ELEKTROTEHNIŠKI VESTNIK 81(3): 86-93, 2014
ORIGINAL SCIENTIFIC PAPER

Mobile Cloud for Telemetry Applications

George Suciu[1], Gyorgy Todoran[1], Anca Apostu[2], Florina Camelia Puican[2], Geanina Ularu[2]

[1]Faculty of Electronics, Telecommunications and IT University POLITEHNICA of Bucharest Bucharest, Romania
E-mail: george@beia.ro
[2]Economic Informatics and Cybernetics Department of Academy of Economic Studies Bucharest, Romania
E-mail: ancaiapostu@gmail.com

Abstract. Since 2008, the term Cloud has become one of the most widely used buzzwords in the IT industry. Lots of researchers and practitioners have tried to define Cloud computing from different application perspectives, but there is not a general consensus about its definition. There is for example not much in common between the Cloud definitions focusing on the use of virtual machines and mobile telecommunication networks and those focusing on the automation of service provisioning and configuration. Unlike most open source Cloud computing technologies, we propose a new decentralized platform for provisioning mobile Cloud services requiring no large farms of servers in data centers. Our focus in this work is on presenting the challenges arising in virtualization of a telemetry application and on showing the measurement results of the proposed solution.

Keywords: mobile cloud; cloud computing; decentralized computing; distributed computing; telemetry

Mobilni oblak za uporabo v telemetriji

Od leta 2008 postaja "oblak" eden najpogosteje uporabljenih modnih izrazov v IT industriji. Veliko raziskovalcev in praktikov je poskušalo opredeliti računalništvo v oblaku iz različnih zornih kotov, toda še vedno ni bilo doseženo soglasje glede enotne definicije. Na primer, ne moremo najti veliko skupnih lastnosti med definicijo oblaka, ki je primerna za uporabnike virtualiziranih računalnikov za mobilno komunikacijsko omrežje, in definicijo oblaka, ki je usmerjena v avtomatsko nudenje storitev in konfiguracije oblaka. V nasprotju z večino odprtih tehnologij v oblaku v članku predlagamo novo decentralizirano platformo za nudenje mobilnih storitev v oblaku, ki ne potrebujejo velikih strežniških skupin v podatkovnih centrih. V našem delu je poudarek na predstavitvi izzivov, ki nastanejo pri virtualizaciji aplikacij v telemetriji in v prikazu merilnih rezultatov, pridobljenih s predlagano rešitvijo.

1 INTRODUCTION

Falling producer prices and rising costs of production are increasingly forcing agricultural businesses to optimize their production costs [1]. Therefore "precision farming", the selective use of inputs such as water, fertilizers or chemicals, is now indispensable in modern agriculture. The growing environmental awareness of consumers further accelerates the process of production optimization and promotes the usage of remote automatic monitoring systems for field information such as the one we propose [2].

In previous approaches, RTUs (Radio Transmission Units) were in most cases implemented on a server connected in a local area network that could not be accessed over the Internet and no company could aggregate enough sensor data to consider automating the treatment process and providing the required resilience [3].

In this paper we propose a cloud platform for telemetry applications to show the mobile users the measurement results of monitoring environmental parameters in agriculture. We use different types of RTUs and sensors that monitor and transmit important data such as temperature, precipitation, wind speed and leaf wetness from selected locations.

Migrating the existing heterogeneous and legacy-distributed applications towards the Cloud, by using tool assisting portability frameworks, can be a complex process [4]. Indeed, virtual machines and mobile communication systems have the potential to merge into opportunistic networks, where the performance of the routing algorithms can be improved by adding social data [5]. Furthermore, pure mathematical models for the web services allocation guided by the reputation need to be improved for implementing an efficient allocation and accurately determining the best endpoint of a web service deployed in a distributed SOA (Service Oriented Architecture) based environment, depending on the constraints of the client that invoked it and on the capabilities of each replica [6].

In this paper we introduce SlapOS [7], the first open source operating system for Decentralized Cloud Computing. The SlapOS Master follows an Enterprise Resource Planning (ERP) model to handle both process allocation optimization and billing. SLAP stands for “Simple Language for Accounting and Provisioning” [19].

Our cloud testing environment provides a platform for processing data from hundreds of different sensors,

Received 16 December 2013
Accepted 9 May 2014

enabling the analysis of the environmental data through a large sample of RTUs.

RTUs transmit the sensor data over GSM/GPRS to our Cloud platform where we conveniently process the site-specific weather and soil data in near real-time, display it in our web-based visualization application and provide detailed recommendations when and where to spray and how much to irrigate - resulting in an optimized yield, quality and income.

Using our system helps tracking pathogen development, optimizing treatments to hit a disease dead on, warning of frost, producing crops as environmentally friendly as possible and improving agricultural risk management.

We foresee that the next years will bring further steps towards mobile virtualization. In the race for faster, better, cheaper and more secure handsets, mobile virtualization is certain to become an important element. "Mobile virtualization also extends to netbooks like iPads, further blurring the distinction between typical desktop virtualization on PCs and mobile devices". The assumption of paper [14] presented in 2010 that virtualization vendors will in fact integrate mobile virtualization features into their existing desktop virtualization product lines was correct.

Paper [11] refers to virtualization and modularization as the main purpose of integration in the context of software architecture and design principles: "integration on the data source level, deployment of independent services, loosely coupled and able to compound themselves into new complex service structures with a minimum effort, binary decoupling using versioning, including business entities and business functionalities."

The detail mentioned in[8] is worth the while of being paid attention: moving among single types of Cloud like IaaS, for example, is less challenging by leveraging an open virtualization format that allows cloud-users to deploy their virtual appliances at any Cloud provider.

Also to be mentioned are the current challenges faced by mobile devices in the Cloud. They should be to considered for future approaches in research papers:

- Mobile device capabilities are increasing:
  - Approaching functionality of the standard PCs – lately, mobile devices have proved to be as feasible as PCs and also offer a constant increase in features and resources;
  - Rich application development/delivery – a variety of applications are deployed lately on mobile devices, covering diverse areas of interest and activities for users;
  - iPhone, Android, Meego, Symbian, WM, etc. – these are the main examples when the topic of mobile computing comes into discussion lately.
- Enticing target for malware authors
  - Mobile banking transactions – the newest challenge when it comes to securing the banking information;
  - Spying on business/enterprise users
- Need of malware detection/mitigation [15]

The paper is structured as follows: Section II describes the concepts of the proposed Cloud telemetry architecture. Section III presents the adopted research methodology framework and measurement results for the agriculture telemetry application. In section IV, the conclusions obtained from the telemetry application are summarized.

2 CLOUD TELEMETRY CONCEPTS

In this chapter we provide an overview of the mobile Cloud components and in explain virtualization and Cloud architecture.

2.1 Traditional Servers vs. Virtualization and Cloud Computing Paradigms

The virtualization paradigm has brought a major transformation on the IT market. Today, there are many ways to deploy virtualization and it might be difficult to select the best solution. First, - the system requirements should be technically analysed -. However, with so many virtualization options to choose from, selecting the right solution can be difficult. In order to obtain a competitive advantage on an IT market, the solution needs to provide efficiency, flexibility, speed and costs advantages.

The performance of an organization relies on the performance of the core businesses and their availability. Companies spend a lot on maintaining a good performance of their applications and update them as necessary. Companies with high needs of optimization and efficiency achievement are the ones who adopt virtualization technology. Virtualization in the Cloud frame enables usage of fast and flexible services which are easily accessed from anywhere.

The virtualization paradigm encompasses separation of computing technology from the hardware resources. It dramatically transforms the process of operating risks and costs on the used technology. The virtualization technology simulates the computing resources, like servers, memory, storage systems and applications. Virtual environments are created by the virtualized servers and they permit to have various applications and servers to run on one computer. The basic notion of virtualization rose almost forty years ago. Everything started with the technology comprised of the client-server networks with multitasking servers and evaluated to users with access to virtual machines [17].

The notion of the server brings together applications, storage, the hardware part and the operating systems. It is very important to have a multiple server service implemented, due to the fact that, in case there are failures experienced, the system can continue without major impacts. On the other hand, the servers that run one workload are not utilized at their full capacity. These servers can be considered more as simple hardware resources than as workload demands. The cluster environment has its restrictions in terms of scalability and it is very expensive. Servers under systems with the virtualization technology assume optimized resource sharing and usage.

The virtual server notion puts away the hardware part from the server software. Cloud computing places virtualization to the next step, where one is able to setup virtual servers, running on a large server cluster from a particular location and where the operating system and the needed application can be selected. The virtualization technology implies reaching the strategic aim of providing flexibility and fast deployment of services in the companies. [18]

2.2 Cloud, Virtualization and Mobile Devices - New Premises for Application Performance Management and Big Data Analysis

Smartphones are rapidly growing and their increasing popularity is expected to surpass the stationary computing devices [8]. As mentioned in paper [10], “the proliferation of mobile devices towards fulfilling the ever-increasing outlooks of the end-user is decelerated by their restrained resources, especially the un-renewable energy.” Employing the Cloud-computing technology in mobile computing has created Mobile Cloud Computing (MCC) that is aimed at with multiple visions: computing augmentation, storage extension, cost reduction, battery conservation, and data-safety enhancement. The abundant opportunities of the Cloud are expected to enhance the computing experience of nearly 240 million mobile business users in few years and drive in the revenue of more than US$5 billion [9].

Virtualization is a term that refers to abstraction of the computer resources. At the moment, probably most of the servers of the companies are already virtualized, and probably everyone’s desktop PC or laptop will soon be. The cost-reduction benefit (among others) is a clear driver for the businesses choosing to virtualize their server infrastructure [20]. Below we show what the driver for mobile virtualization is.

In [11] virtualization is defined as well established technology in the desktop and server domain. Virtualization is currently investigated and analyzed with respect to its potential when used for the mobile devices. As explained in [12], virtualization of the mobile devices, such as smartphones, tablets, netbooks, and MIDs, offers a significant potential in addressing the mobile manageability, security, cost, compliance, application development and deployment challenges of the today`s enterprises. “Advances in mobile processor performance, memory and storage capacities have led to the availability of many of the virtualization techniques that have previously been applied in the desktop and server domains.” To- leverage these opportunities, the VMware's Mobile Virtualization Platform (MVP) makes use of system virtualization to deliver an end-to-end solution for facilitating the employee-owned mobile phones in the enterprise. In this paper we describe the main benefits of the mobile virtualization and describe the key aspects of both the core and platform virtualization on mobile devices.

In2008 and 2009, the commercial interest shifted from the “grids” to the “clouds” with the availability of several on-demand compute and storage resources. The “grid” and the “Cloud” concepts are independent and complimentary. Their similarities are in their both aiming to provide access to a large compute (CPU) and storage (disk) resource. Beyond that, a Cloud utilizes virtualization to provide a uniform interface to a dynamically scalable underlying resource, enabling the virtualization layer to conceal physical heterogeneity, geographical distribution and faults [12].

According to Gartner [13], “by 2012, more than 50% of the new smart phones shipped will be virtualized”. During 2011, the players in the virtualization industry entered the mobile space with outstanding announcements and calculated acquisitions.

- VMware, the market leader in the server virtualization, presented its Mobile Virtualization Platform (MVP)[16] prototype that allowed two different OS to be running on the same device, only one year after purchasing Trango.
- Open Kernel Labs, who focused on the mobile phones from the beginning and it is now present in more than 300 million smartphones, recently announced the Motorola Evoke QA4 as the first virtualized terminal.
- Citrix focused more on the access to the virtualized servers from the mobile devices and on how to run real PC applications from your phone, like this receiver for Android.

The above players in the mobile virtualization provide a most appropriate image about the new possibilities and opportunities to be achieved with virtualization. New improvements in technology, architecture and also in the business models between the manufacturers, OS vendors and developers are already ongoing and provide an interesting relation with the desktop as a service (DaaS) [13].

2.3 Benefits of Mobile Virtualization

The benefit of the mobile virtualization for the mobile devices is a thin layer of software embedded on the phone to decouple the operating system, applications and data from the underlying hardware. On the top of this layer, a selected operating system can be deployed, reducing the development time and getting the mobile phones to the market faster by using over-the-air updates.

However, the mobile phones are not like the PC's. They have a Real-Time Operating System (RTOS) that performs critical tasks: voice compression, PIN access, base-band radio, encryption, etc. It's here where the different approaches to the mobile virtualization differ, reaching different levels of security, isolation, stability and integration.

In the last two years many interesting trends in the area of the Cloud, Virtualization and Big data have been developed. There has been an exponential increase in the number of applications, end users and devices, all contributing to an increase in the volume of activity. Applications have been redesigned to handle these new volumes and infrastructure resources that need to provide a platform capable for these new levels of demand.

Coupling the above with the user expectation of the application to behave like the Google searches and respond within one second - Application Performance Management (APM)is facing new challenges and needs a new breed of solutions. With the exponential increase in the user traffic and the derived exponential increase in the number of the application and infrastructure components interacting with each other, APM has become a "Big Data" problem on its own. The amount of the data needing to be analyzed in real-time puts APM in the "Big Data" space and the APM solutions need to be able to technically deal with the huge amounts of data as well as bursts of traffic in peak times and other seasonal impacts [13].

In 2013, we will continue to see huge increases in the Cloud deployments, both the public and private, both IaaS (Infrastructure as a Service) and PaaS (Platform as a Service). Enterprises will be able to deploy and rollout faster, and leverage more of their investments, providing their business with more agile capabilities. This will put APM in a much more strategic position than so far. As the Cloud technologies simplify a lot of the operational aspects, performance management becomes more complex and is of greater importance than ever [13].

The mobile virtualization supports the mobile cloud computing. It seems that some of the latest challenges concerning the mobile cloud computing is the handset or smartphone virtualization. Creating completely separate profiles through virtualizing the handset opens completely new possibilities in terms of the usage scenarios. This includes, for example, integrating both a business and a personal profile in the same device without coinciding any information or application. Storing copies of the profile(s) in the Cloud means that users can replicate and shift between devices while still maintaining the same profile and keeping a high level of data assurance by storing the data in the Cloud.

VMware has introduced its mobile Cloud platform, called Mobile Virtualization Platform (MVP) that is aimed at supporting separate personal and corporate profiles on the same handset, e.g. an employee-owned handset. Each profile runs in a completely isolated container so that OS's, applications and data belonging to each profile, personal or corporate, are only accessible within the appropriate profile. So, running a hypervisor on the handset directly will isolate the profiles and create a virtualized infrastructure.

VMware has announced a partnership with LG Electronics for running MVP on an Android enabled LG smartphone. With the rising smartphone sales, the need for a combined work-personal smartphone has become increasingly stronger – as most users prefer to carry only one handset. Using virtualization at the handset level seems to solve many of the associated security challenges and risks as the work related and personal profiles should be completely separated and isolated. Normally, this would include apps, contacts and data, several organizations such as ETSI, ENISA or EuroCloud working together to harmonize the criteria for trusted Cloud computing at the European level [21].

Another important player in the mobile virtualization domain, OK Labs, has developed a "Microvisor" (a mobile hypervisor) that was in 2009 installed in the Motorola Evoke QA4, probably making it the world's first virtualized smartphone [17].

The three main benefits of the mobile virtualization identified by some experts include:

- Convergence of the corporate/personal profile
- Smartphone capabilities on feature phones (or device commoditization)
- Faster development of the new phone variants and fragmentation reduction

Other important benefits are the lower cost phones through faster development times and increased security through isolated user profiles.

In the next paragraph we will present the architectural side of mobile computing with a direct reference to the Mobile IPv6.

2.4 Mobility Management Issues in Mobile Cloud Computing - Mobile IPv6 and the Cloud

Lately, mobile computing [10] and Cloud have represented an area of a high interest for the industry and academic researchers. The need for scalable, heterogeneous and available resource management and content delivery have been the main factors for the development of the new mobile cloud computing architectures addressing important aspects like mobility management, resource offloading, mobile device-assistant sensing and mobile service composition.

The mobile IPv6 was developed based on the IPv6 with an added functionality for mobile connections. The mobility function implies that the host supporting Mobile IPv6 can change its position to the IPv6 Internet free. The connection is held by paring the source address and the destination address. There is a problem when the host is not supporting, the mobile IPv6 leading to a loss of the connections when the position and thus the point of attachment is changed. The reason is the fact that the IPv6 address of a node is based on the network prefix. When the host has left the network and has entered another one, the address becomes invalid. This happens because the IP address is used for two purposes. It either identifies the node or carries the information about the location. In order to solve this problem, the main concept of the future mobile IPv6 is to have a second IPv6 address to a host that will serve as an identifier. The idea is that this new address will differ from the one of the network the device is attached to. The new address will be a fixed one corresponding to the home address. With this fixed address, the connection will not be lost whenever the location is changed.

Fig. 1 presents the Mobile IPv6 way of working. It comprises mobile nodes (MN), home agent (HA) – the anchor point sending information to the Corresponding Node (CN) on the Internet, process of the Binding Update (BU) - registering to a network and the care-of address (CoA) -the IP address for the mobile device when it registers to the foreign network.

Whenever the mobile node moves from one network to other, it captures a care-of address (CoA). After capturing, association between the home and CoA, called binding and done through Binding Update (BU) messages is performed. The home agent keeps records on the binding and intercepts packages sent to the home address of the mobile node and redirects them to the current CoA. Another registration is done to the correspondent nodes, enabling them to send packages directly to MN. The mobility in the IPv6 is performed only by CNs and HA. This means that when their position is far from MN, the BU messages travel through several networks leading to latency and decrease in speed.

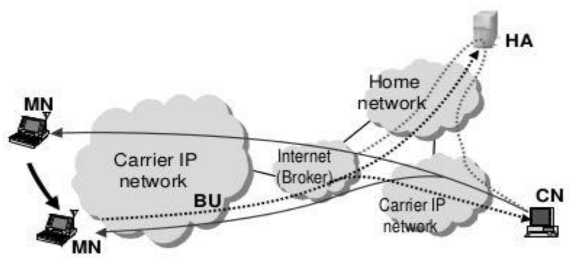

Fig. 1. Mobile IPv6 overview

Another important problem of mobile computing to be solved is deploying applications in different carrier networks by using a common commercial agreement. As seen front Fig. 1, depending on the distance between MN and the CN, all the networks that are passed through shall be covered by such commercial agreement.

For all these problems the term to be used is communication quality, they can be solved by taking important measures, such as bandwidth upgrading or data delivery-time minimization.

3 Telemetry Framework and Measurement Results for Agriculture

To collect the data from RTUs, we developed a test, platform shown in Fig. 2. The GSM/GPRS data transmission can be extended to the areas where there is no coverage by using a UHF bridge operating in the frequency range of 430 – 440 MHz connected to an Internet accessing gateway. Each slave node is divided into a certain number of computer partitions [7], each being same kind of a lightweight secure container. They are based on a UNIX users and directories rather than on virtualization. A typical PC can easily provide 100 computer partitions and can thus run 100 RTU web portals or 100 sensor monitoring sites, each with its own independent database. A large server can contain 200 to 500 computer partitions.

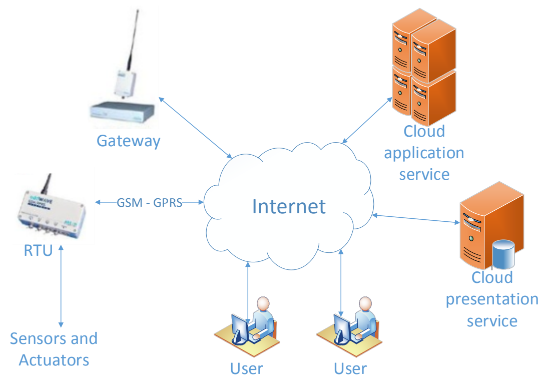

Fig. 2. General architecture of the telemetry system

A computer partition consists of a dedicated IPv6 address, dedicated tap interface (slaptapN), dedicated user (slapuserN) and dedicated directory (/srv/slapgrid/slappartN). The IPv6 greatly simplifies the deployment of SlapOS and the accounting network traffic per computer partition is simplified. Using the IPv6 for the public Clouds helps interconnecting the SlapOS Slave Nodes hosted at home without setting the tunnels or complex port redirections. Using the IPv6 for the private Cloud, replaces the existing corporate tunnels with a more resilient protocol which also provides also a wider and flat corporate addressing space.

By addressing the IPv6, hundreds of IPv6 addresses are allocated on a single server, so that each running process can be attached to a different IPv6 address without changing its default port settings. Of course, this would be possible with the IPv4 or through VPNs, but it would be much more difficult or less resilient.

Our measurement study was made for two grape yards in Romania (Bucharest and Blaj) using our SlapOS decentralized Cloud platform hosted on several server nodes. The platform was based on the Ubuntu Linux – Apache – MySQL software releases and RTU hardware and sensors, as shown in Fig. 3.

The Presentation Service displays the measured data as a table or in the diagram form. There are multiple possibilities for visualizing the dates in different past periods (from a day to a year), showing the values at a specific date, hour, minute and second. Also, there is a possibility of highlighting the average, amount, maximum and minimum registered value for each parameter for the various periods of time, on the user demand.

The system primary and processed data are kept available for the user for two years. This period can be prolonged when requested so by the user. The Application Service issues email warnings about critical situations detected on the monitored water intakes by the system.

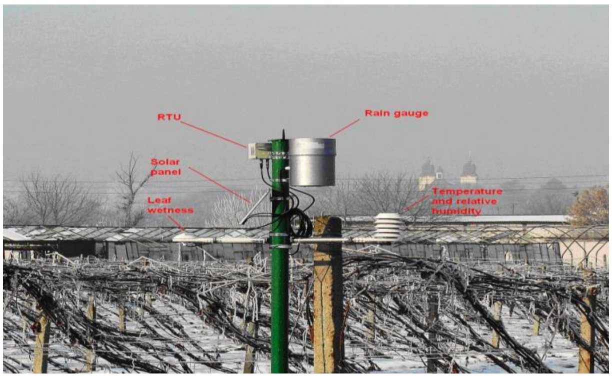

Fig. 3. General Structure of RTU and Sensors

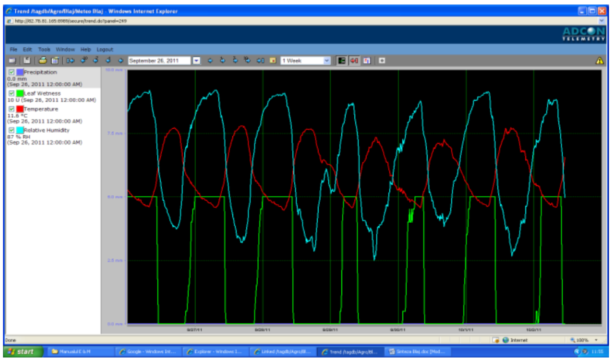

Fig. 4. Measurement results of the climatic parameters from September 26 to October 2, 2011 week

The total rain quantity reported by the system from May – September 2011 was of 222 l/sqm, and the monthly distributions were: May – 33 l/sqm, June – 116 l/sqm, July – 49 l/sqm, August - 5 l/sqm, September – 8 l/sqm. The values of the other climatic parameters, such as Precipitation, Leaf Wetness, Temperature and Relative Humidity are shown in Fig. 4.

Another important parameter that was studied is accumulation of the thermal energy over time. It is known as the degree-days or heat units. The growth and development of plants, insects, and many other invertebrate organisms are much temperature dependent. In other words, a constant amount of thermal energy is required for the various organisms to grow and develop, but the time period over which that thermal energy is accumulated can vary. Many organisms slow down or stop their growth and development when temperatures are above or below their threshold levels. Degree-days and other heat unit measurements were used to determine the planting dates, predict the harvest dates and select the appropriate crop varieties.

The methods, used to calculate the heat unit include: Averaging, Standard, GDD (Growing Degree-Days), Single Triangle, Double Triangle, Single Sine, Double Sine and Near Real-Time. As shown in Fig. 5, the method we used was the Averaging Method, the maximum heat unit (26.3 degree-days) was calculated for July 10, 2011and the total thermal energy accumulated per the crop for October 10, 2011 (3,484.2 degree-days).

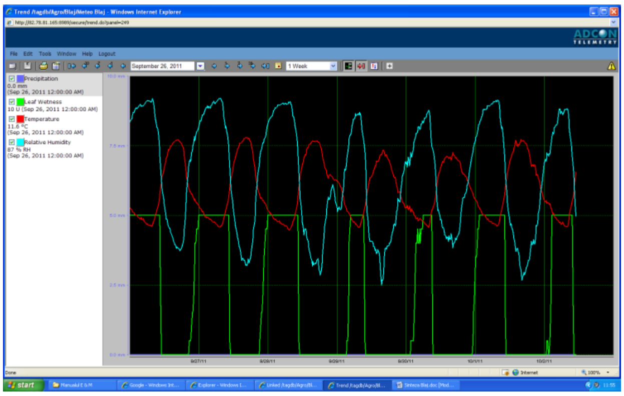

Fig. 5. Heat-unit graphs (daily degree-days and total)

4 CONCLUDING REMARKS

The data provided by the cloud telemetry solution is accessible anytime and anywhere, through Internet, to any person that is able to log in with a username and a password. The server can be accessed from any PC with an Internet access and a general browser and also from other terminals (iPad, iPhone, mobile phone).

The communication between the telemetry equipment and Cloud platform is done through the GSM/GPRS data service. As BTS of the telecom operator is located at a long distance and over important natural obstacles, the GPRS transmission is often damaged, but the data to be transmitted during the interruption are fully recovered after returning to their normal transmission state.

Though the IPv6 is intended to be used to interconnect processes globally on a SlapOS public or private Cloud, some of the existing software on RTUs is incompatible with the IPv6 for several reasons. Sometimes, the IP addresses are stored in a structure of three integers, which is incompatible with the IPv6. Other times, the IPv6 URLs are not recognized since it is only the dot that is recognized as a separator in the IP addresses. This is why we decided to provide for each computer partition a dedicated, local, non routable IPv4 address.

ACKNOWLEDGMENT

This work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/134398.

REFERENCES

[1] T. Fukatsu, T. Watanabe, H. Hu, H. Yoichi, and M. Hirafuji, "Field monitoring support system for the occurrence of Leptocorisa chinensis Dallas (Hemiptera: Alydidae) using synthetic attractants, Field Servers, and image analysis", Computers and Electronics in Agriculture, vol. 80, January 2012, pp. 8–16, 2012.

[2] J.A. Jiang, C.L.Tseng, F.M. Lu, E.C. Yang, Z.S. Wu, C.P. Chen, S.H. Lin, K.C. Lin, and C.S. Liao, "A GSM-based remote wireless automatic monitoring system for field information: A case study for ecological monitoring of the oriental fruit fly, Bactrocera dorsalis (Hendel)", Computers and Electronics in Agriculture vol. 62, Issue 2, July 2008, pp. 243–259, 2008.

[3] G. Suciu, C. Cernat, G. Todoran, V. Suciu, V. Poenaru, T. Militaru, and S. Halunga, "A solution for implementing resilience in open source Cloud platforms", 9th International Conference on Communications, COMM 2012, IEEE Communications Society, pp. 335-338, June 2012.

[4] S. Panica, D. Petcu, I.L. Larrate, and T. M'hr, "Sky Computing Platform for Legacy Distributed Application," Parallel and Distributed Computing (ISPDC), 2012 11th International Symposium on , vol., no., pp.293-300, 25-29 June 2012

[5] R.I. Ciobanu, C. Dobre, V. Cristea, and D. Al-Jumeily, "Social Aspects for Opportunistic Communication," Parallel and Distributed Computing (ISPDC), 2012 11th International Symposium on , vol., no., pp.251-258, 25-29 June 2012.

[6] V.N. Serbanescu, F. Pop, V. Cristea, O.-M. Achim, "Web Services Allocation Guided by Reputation in Distributed SOA-Based Environments," Parallel and Distributed Computing (ISPDC), 2012 11th International Symposium on , vol., no., pp.127-134, 25-29 June 2012

[7] J.P. Smets-Solanes, C. Cerin, and R. Courteaud, "SlapOS: A Multi-Purpose Distributed Cloud Operating System Based on an ERP Billing Model," IEEE International Conference on Services Computing (SCC), pp.765-766, July 2011.

[8] OVF, Open Virtualization Format Specification, Acceesible from: www.dmtf.org/sites/default/files/standards/documents/DSP0243_1.0.0.pdf, 2009.

[9] A. Ranabahu and A. Sheth, "Semantics Centric Solutions for Application and Data Portability in Cloud Computing", Cloud Computing Technology and Science, IEEE Second International Conference 2010, pp. 234 - 241.

[10] Zohreh Sanaei, Saeid Abolfazli, Abdullah Gani and Rashid Hafeez Khokhar, "Tripod of Requirements in Horizontal Heterogeneous Mobile Cloud Computing", Latest Advances in Information Science and Applications, pp.217-222, ISBN: 978-1-61804-092-3

[11] Manole Velicanu, Daniela Litan, Larisa Copcea(Teohari), Mihai Teohari, Aura-Mihaela Mocanu(Virgolici), Iulia Surugiu, Ovidiu Raduta, "Ways to Increase the Efficiency of Information Systems", Recent Researches in Artificial Intelligence, Knowledge Engineering and Data Bases, pp.211-216, ISBN: 978-960-474-273-8

[12] Tatiana Kovacikova, "Grid and Cloud Computing Integration with NGN", Proceedings of the 13th WSEAS International Conference on COMMUNICATIONS, Rodos, Greece, 2009, pp.88-94, ISSN: 1790-5117, ISBN: 978-960-474-098-7

[13] Olafur Ingthorsson, "Mobile virtualization supports mobile cloud computing", December 22, 2010 http://cloudcomputingtopics.com/2010/12/mobile-virtualization-supports-mobile-cloud-computing/

[14] http://vmblog.com/archive/2012/12/05/correlsense-predictions-cloud-virtualization-and-mobile-devices-drive-the-market-into-a-new-breed-of-apm-and-big-data-analysis.aspx

[15] Jörg Brakensiek, Axel Dröge, Martin Botteck, Hermann Härtig and Adam Lackorzynski, "Virtualization as an enabler for security in mobile devices", Proceeding IIES '08 Proceedings of the 1st workshop on Isolation and integration in embedded systems, pp.17-22

[16] Ken Barr, Prashanth Bungale, Stephen Deasy, Viktor Gyuris, Perry Hung, Craig Newell, Harvey Tuch and Bruno Zoppis, "The VMware mobile virtualization platform: is that a hypervisor in your pocket?", Newsletter ACM SIGOPS Operating Systems Review archive, Volume 44 Issue 4, December 2010, pp.124-135

[17] http://www.vmware.com/solutions/cloud-computing/index.html

[18] http://www.virtualizationpractice.com/

[19] G.Suciu, V.A. Poenaru, C. G. Cernat, G. Todoran, T.L. Militaru, ERP and E-Business Application Deployment in Open Source Distributed Cloud Systems, *The Eleventh International Conference on Informatics in Economy IE*, pp. 12-17, 2012.

[20] D. Verber, Is the future of mobile computing in the clouds?, *Proceedings of the 1st International Conference on CLoud Assisted ServiceS (CLASS)*, pp. 6-14, 2012.

[21] D. Baskovc, A. Weiss, B. Becker, Cloud Standardization, Compliance and Certification, *Proceedings of the 1st International Conference on CLoud Assisted ServiceS (CLASS)*, pp. 15-19, 2012.

George Suciu received his B.Sc., M.Sc. degrees from the Faculty of Electronics, Telecommunications and Information Technology at the University "Politehnica" of Bucharest, and from the Faculty of Cybernetics, Statistics and Economic Informatics of the Academy of Economic Studies Bucharest Romania, respectively. Currently, he works after his Ph.D degree in the field of cloud communications, big data, open source and IoT/M2M. He is an IEEE member and has received a type D IPMA certification. He is the author or co-author of over 30 journal papers and scientific papersin the field of: project management, electronics and telecommunication, cloud computing, data acquisition and signal processing.

Anca Apostu received her B.Sc. and M.Sc. degrees from the Academy of Economic Studies of Bucharest (Romania), Faculty of Cybernetics, Statistics and Economic Informatics in 2008 and 2010, respectively. Presently, she is a post-graduate student of the Economic Informatics. The title of her Ph.D. thesis is: "Informatics solution for unitary tracking prices in a distributed environment". Her scientific fields of interest include: Economics, Databases, Programming, Information Systems, Information Security and Distributed Systems.

Florina Camelia Puican received her B.Sc. degrees from the Faculty of Business Administration in teaching in foreign languages (English) at the Academy of Economic Studies, Bucharest and from the Faculty of Mathematics and Computer Science, Section Computer Science, University of Bucharest, Romania in 2008 and 2009, respectively, and her M.Sc. degrees from the latter Faculty in teaching in foreign languages (English), a. During her studies and work a she has acquired a wide range of skills in economics, information technology and information systems for business, design and management of information systems and databases. Currently she is a postgraduate student at the Institute of Doctoral Studies, Bucharest.

Elena-Geanina ULARU received her B.Sc. and M.Sc. degrees from the Faculty of Cybernetics, Statistics and Economic Informatics of the Academy of Economic Studies of Prague, the Czech Republic, in 2008, respectively. she works towards her Ph.D degrees, at the Institute of Doctoral Studies, doing her research at the University of Economics of Prague.