CrossMark

# Big Data Processing for Renewable Energy Telemetry Using a Decentralized Cloud M2M System

George Suciu[1] · Alexandru Vulpe[1] · Alexandru Martian[1] ·
Simona Halunga[1] · Dragos Nicolae Vizireanu[1]

**Abstract**  Hydro-, Aeolian and Solar energy show significant promise in helping to reduce pollutants and greenhouse gases, which is a primary focus in today's sustainable development culture. To enjoy the power of them, the human society needs solutions to transform the energies mentioned above into electric energy, at specific reliability, efficiency and sustainability parameters. Maintaining this kind of parameters implies, among other things, the careful and permanent monitoring of equipment. The monitoring process implies remote monitoring, as we are talking about preserving natural resources. The equipment is mostly situated in the middle of nature, covering large areas mostly outside of populated locations. In their great majority installations for wind and solar energy have been designed and manufactured relatively recently, which makes them contain systems of tele-monitoring that are designed and included by default, as a part of great importance to the entire investment. The situation is different in the case of hydroelectric plants, which have a tradition of over 130 years and have been and are still built to this day. Renewable energy sources are being increasingly used and need to be constantly monitored for optimizing the power grid. Unfortunately, such micro power plants are located in difficult to access remote locations where often only satellite or sparse GSM radio signals are available. In this paper we study the way how to process big data gathered by a

✉ George Suciu
  george@beia.ro

  Alexandru Vulpe
  alex.vulpe@radio.pub.ro

  Alexandru Martian
  martian@radio.pub.ro

  Simona Halunga
  shalunga@elcom.pub.ro

  Dragos Nicolae Vizireanu
  nvizireanu@comm.pub.ro

[1]  Faculty of Electronics, Telecommunications and Information Technology, University Politehnica of Bucharest, 060071 Bucharest-6, Romania

decentralized cloud system, based on general systems and remote telemetry units (RTUs), for tele-monitoring of renewable energy objectives. Also, we analyze a proposed cloud M2M system, where each RTU communicates by radio with a telemetry data gateway connected to a cloud computing infrastructure equipped with appropriate software that delivers processed data. Furthermore, we present how we use a search based application built on Exalead CloudView to search for weak signals in big data. In particular, given the telemetry application, we propose to leverage trivial and non-trivial connections between different sensor signals and data from other online environmental wireless sensor networks, in order to find patterns that are likely to provide innovative solutions to existing problems. The aggregation of such weak signals will provide evidence of connections between re-newable energies and environmental related issues faster and better than trivial mining of sensor data. As a consequence, the software has a significant potential for matching environmental applications and challenges that are related in non-obvious ways. Finally, we present the measurement results for a hydro-energy case study and discuss the applicability for other renewable sources such as solar or wind energy.

**Keywords**   Cloud · IoT · Big data · M2M · Renewable energy

## 1 Introduction

Cloud computing and Internet of Things (IoT) are nowadays two of the most prominent and popular ICT paradigms that are expected to shape the next era of computing.

The IoT paradigm relies on the identification and use of a large number of heterogeneous physical and virtual objects (i.e., both physical and virtual representations), which are connected to the internet [1]. IoT enables the communication between different objects, as well as the in-context invocation of their capabilities (services) towards added-value applications. Early IoT applications are based on radio frequency identification (RFID) and wireless sensor network (WSN) technologies and deliver tangible benefits in several areas including manufacturing, logistics, trade, retail, green/sustainable applications, as well as other sectors. Furthermore, the European Commission has already co-funded a number of FP7 projects (e.g., IOT-A, iCore, BUTLER) [2], which have researched the main building blocks of IoT systems (including reference architectures) and have built innovative added-value applications.

At the same time, the cloud computing paradigm [3] realizes and promotes the delivery of hardware and software resources over the Internet and according to an on-demand utility based model. Depending on the type of computing resources delivered via the cloud, cloud services take different forms such as Network as a Service (NaaS), Infrastructure as a service (IaaS), Platform as a service (PaaS), Software as a service (SaaS), Storage as a service (STaaS) and more. These services hold to promise to deliver increased reliability, security, high availability and improved QoS at an overall lower total cost of ownership (TCO). Similarly to the case of cloud computing, the EC has already co-funded a number of projects (e.g., RESERVOIR, VISION-CLOUD, OPTIMIS, CONTRAIL) [2], which have developed pan-European prototypical cloud infrastructures, while they have also built relevant cloud technologies (e.g., resource management, security) and applications.

Another common aspect of IoT applications is that many of them of practical interest involve control and monitoring functions, where human-in-the-loop actions are not

required. As a matter of fact, the only reason for having many of these applications is to remove human intervention for improved efficiency, security, and safety. We focus specifically on these applications, which we call machine-to-machine (M2M), which will create a bridge between the real world (made of sensors, actuators, tags that are pervasive in our lives) and the virtual world (the Internet and its associated services).

In the case of M2M, important research initiatives are proposing new reference models, defining standards and new communication architectures, with different approaches for solving security, reliability and energy-efficiency problems. However, many efforts are focused on largely distributed critical infrastructures and just a few initiatives are dedicated to the definition of platforms for deployment and execution of new M2M applications, based on new generations of WSN and innovative sensor mining methods that can be deployed according to a cloud computing model.

Indeed, M2M applications are envisioned to be hosted within cloud computing systems and contribute to the converge of interactions between the real and virtual world, thus accomplishing improvements in industrial productivity and quality of life for citizens, based on secure and dependable automation of sensing and actuating tasks.

However, we argue that this kind of approach is sub-optimal for M2M because of its inherent paradigms: M2M applications are highly autonomous, implement simple and repetitive interactions in highly constrained environments, with limited scope in time and space, and must respond in a reliable manner to mission critical QoS needs, whereas usual cloud applications require that big volumes of data are redundantly stored and provided through content delivery networks, to be available for very long periods and accessible as ubiquitously as possible for the use by human beings.

The paper is organized as follows. Section 2 presents an overview of the state of the art in Cloud Computing, IoT and M2M, while Sect. 3 presents a cloud computing architecture for telemetry. Section 4 presents Big Data processing involved in the previously mentioned architecture and the results achieved by using it in a real life scenario for hydro-energy telemetry implementation. Finally, Sect. 5 draws the conclusions and presents envisioned future work.

## 2 State-of-the-Art Review

### 2.1 Convergence Between Cloud and IoT

Since the early instantiations/implementations of both technologies, it has become apparent that their convergence could lead to a range of multiplicative benefits. Most IoT applications entail a large number of heterogeneous geographically distributed sensors. As a result, they need to handle many hundreds (sometimes thousands) of sensor streams, and could directly benefit from the immense distributed storage capacities of cloud computing infrastructures. Furthermore, cloud infrastructures could boost the computational capacities of IoT applications, given that several multi-sensor applications need to perform complex processing that is subject to timing (and other QoS constraints). Also, several IoT services (e.g., large scale sensing experiments, smart city applications) could benefit from a utility-based delivery paradigm, which emphasizes the on-demand establishment and delivery of IoT applications over a cloud-based infrastructure.

The proclaimed benefits of the IoT/cloud convergence have (early on) given rise to research efforts that attempted to integrate multi-sensory services into cloud computing

infrastructures [4]. The most prominent of these efforts are the so-called sensor-clouds, which blend sensors into the data centre of the cloud and accordingly provide service oriented access to sensor data and resources [5]. Several recent research initiatives are focusing on real-life implementation of sensor clouds, including open source implementations [6]. Note that such initiatives are in progress both in the US [7] and in the EU [8], aiming at developing middleware infrastructures for sensor-clouds, which will enable the on-demand delivery of IoT services.

In addition to research efforts towards open source sensor-clouds, there are also a large number of commercial on-line cloud-like infrastructures, which enable end-users to attach their devices on the cloud, while also enabling the development of applications that use those devices and the relevant sensor streams. Such commercial systems include COSM [9], ThingsSpeak [10], and Sensor-Cloud [11]. These systems provide tools for application development, but they offer very poor semantics and no readily available capabilities for utility based delivery. There is also a number of other projects which have been using cloud infrastructures as a medium for M2M interactions (e.g., [12]), without however adapting the cloud infrastructure to the needs of the IoT delivery.

In the area of IoT applications (e.g., for smart cities), we are also witnessing cases of IoT/cloud convergence. For example, in the scope of ICT-PSP project RADICAL [13], the partners will be deploying sensor streams over the BONFIRE cloud infrastructure, as means to benefitting from the cloud's storage capacity and applications hosting capabilities. A similar approach is followed in the scope of the FP7 SmartSantander project [14]. Note that smart cities is a privileged domain for exploring and realizing the IoT/cloud convergence, given that such applications need to manage and exploit a large number of distributed heterogeneous sensor streams and actuating devices.

Regarding the area of Cloud M2M concept for renewable energy, there is ongoing standardisation work in M2M communications followed by the application of M2M communications especially to smart grids [15, 16]. Also, a middleware perspective for telemetry is proposed by unifying M2M, SCADA, WSN and RFID technologies into IoT in the cloud [17]. An approach for data analytics for M2M and smart energy grid is discussed based on smart meter data mining and machine learning [18]. Even though cloud computing is considered efficient for smart energy grids, there are some drawbacks, such as security and reliability needed for critical infrastructures [19]. Furthermore, sensor-based M2M agriculture monitoring systems are being adapted for developing countries for monitoring renewable energy sources and smart green buildings [20, 21].

## 2.2 Big Data

The European Union has declared Big Data as a priority for Horizon 2020, the EU's next European research framework. This is confirmed by the theme and budget of the last FP7 ICT call for projects to be started in 2014 [22, 23].

The plethora of data types and formats (structured, unstructured, semistructured or multistructured) as well as the diversity of generating sources (sensors, devices, social networks, web content, mobile phones, etc.) generates a large variety of data. According to Tech Target [24], multistructured data already represents 80 % of the volume of data that is available in an organization.

The economic potential of Big Data represents the greatest challenge and it consists of finding value in the large volume of unstructured data in (near) real time. The tendency to use this information for business analytics is becoming a worldwide management practice.

Fruitful sources of data, recently come to attention (IoT, sensor networks, social networks) have given an unprecedented growth rate of the volume of available microeconomic and macroeconomic data. It is estimated that in the year 2012 alone, 2.5 ExaBytes of data have been generated daily [25].

Big Data and their management (generating, storing, indexing, and searching) is a worldwide challenge because multiple factors, of which we mention:

- *The need for highly skilled labourers* A Gartner study [26] from 2012 estimates the creation of 4.4 million new jobs globally in relation to Big Data.
- *Environment problem monitoring* warping dams, proactive maintenance and repair, using satellite imaging to monitor changes in the Earth's crust (earthquakes, erosion, floods, and landslides).
- *Smart City management* this is based on gathering, managing and analysing large volumes of data regarding car and passenger traffic, the evolution of environmental factors, energy consumption dynamics, high risk situation monitoring etc. [2].

Variable prices and rising costs of production are forcing energy producers to optimize production costs. Therefore "precision energy production", the optimized use of natural energy resources such as water, sun or wind is now indispensable. The growing environmental awareness of consumers further accelerates this process and promotes the usage of remote automatic monitoring system for field information such as the one we propose. By running the M2M software over virtual machines it is possible to optimize the network performance and improve the energy consumption for the devices that are powered by batteries [27].

In previous approaches remote telemetry units (RTUs) were implemented in most cases on a local server and no company could aggregate enough sensor data to consider automating the production process and providing the required resilience [28]. Furthermore, by using low power sensors and data aggregation the energy consumption of the M2M network can be optimized [29].

Some studies show that Cloud computing can actually make traditional datacentres more energy efficient by using technologies such as resource virtualization and workload consolidation [30]. Contrary to the above opinion, other studies, for example Greenpeace [31], observe that the Cloud phenomenon may aggravate the problem of carbon emissions and global warming.

## 3 Components of the Cloud Telemetry Architecture

To illustrate the need for interconnecting extremely heterogeneous sensors and gateways we consider the following example scenarios, which show short-term realistic applications of smart things enabled by M2M communication:

- *Continuous care* Citizens affected by chronic diseases can be provided with sensors continuously monitoring relevant health parameters, which produce data that are conveyed through a smart phone to a remote centre for real-time analysis. In case a potentially dangerous situation is detected an alarm can be fed back to the smart phone.
- *Ambient assisted living* Activity detection sensors installed in houses where senior or disabled citizens live send data to a remote centre, so as to generate alarms in case anomalies are detected with respect to a typical pattern (e.g., prolonged lack of movement during daytime).
- *Smart grid* The distribution system operator (DSO) provides the smart meter of a house with information on the next-house cost of electricity. Based on this piece of

information, possibly combined with other sources (e.g., power currently generated by solar panels), a remote control system can switch on/off smart electric appliances.

- *Traffic management* Road-side units (RSU) are placed along roadways to monitor the flow of vehicles. Based on the information collected from a given area, a remote centre can identify congestions and provider drivers with real-time feedback to reduce travel times, hence $CO_2$ emissions.
- *Fleet management* Vehicles provide the intelligent transportation infrastructures with information on their location and health status, by allowing a remote control system to optimize logistics or track dangerous goods, for commercial vehicles only, and provide all drivers with improved safety or advanced services (e.g., pay-as-you-go insurance).

### 3.1 Cloud Architecture

SlapOS is based on a Master and Slave design, as shown in Fig. 1. In this paper we are going to provide an overview of SlapOS architecture and are going in particular to explain the role of Master node and Slave nodes, as well as the software components which they rely on to operate a distributed cloud for telemetry applications. Slave nodes request to Master nodes which software they should install, which software they show run and report to Master node how much resources each running software has been using for a certain period of time. Master nodes keep track of available slave node capacity and available software. Master node also act as Web portals and Web service so that end users and software bots can request software instances which are instantiated and run on Slave nodes.

Master nodes are stateful. Slave nodes are stateless. More precisely, all information required to rebuild a Slave node is stored in the Master node. This may include the URL of
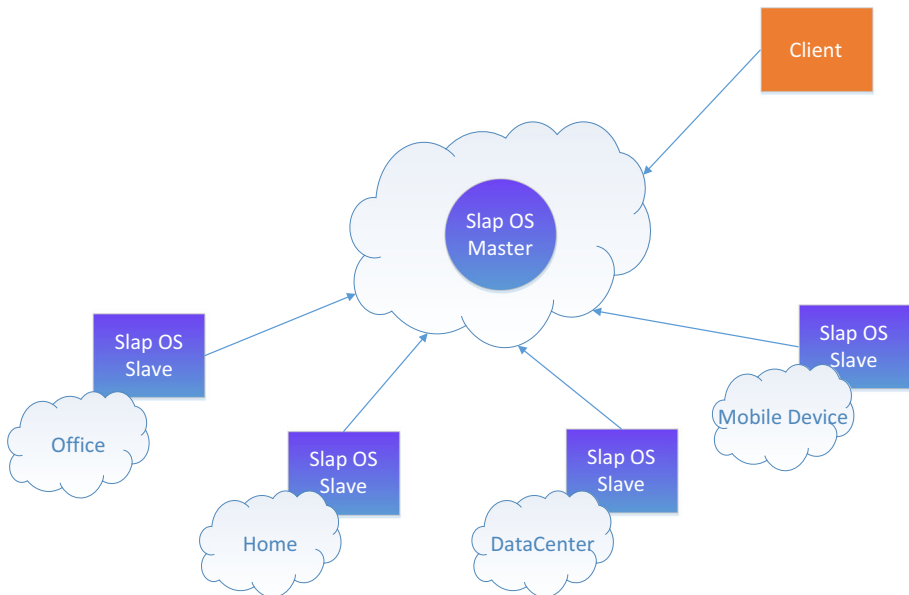


**Fig. 1** SlapOS master—slave cloud architecture

a backup service which keeps an online copy of data so that in case of failure of a Slave node, a replacement Slave node can be rebuilt with the same data.

It is thus very important to make sure that the state data present in Master node is well protected. This could be implemented by hosting Master node on a trusted IaaS infrastructure with redundant resource. Or—better—by hosting multiple Master nodes on many Slave nodes located in different regions of the world thanks to appropriate data redundancy heuristic. We are touching here the first reflexive nature of SlapOS. A SlapOS master is normally a running instance of SlapOS Master software instantiated on a collection of Slave nodes which, together, form a trusted hosting infrastructure. In other terms, SlapOS is self-hosted.

SlapOS Slave nodes are relatively simple compared to the Master node. Every slave node needs to run software requested by the Master node. It is thus on the Slave nodes that software is installed. To save disk space, Slave nodes only install the software which they really need.

Each slave node is divided into a certain number of so-called computer partitions. One may view a computer partition as a lightweight secure container, based on UNIX users and directories rather than on virtualization. A typical barebone PC can easily provide 100 computer partitions and can thus run 100 RTU web portals or 100 sensors monitoring sites, each of which with its own independent database. A larger server can contain 200–500 computer partitions.

### 3.2 M2M Telemetry Architecture

In Fig. 2 we present the general structure of the system that we propose for the tele-monitoring of installation sites in hydro power stations.

At each of the monitored installation sites a system is set up composed mainly from distant RTUs, sensors and actuators. RTUs capable to communicate with the Gateway through GSM-GPRS and Internet will be used in standard configurations. For the installation sites which are situated in no GSM coverage areas, RTUs in the UHF band of 430–440 MHz will be used. These will communicate with the date concentrator through a bridge station (bridge) which will ensure the UHF-GPRS and GPRS-UHF conversion.
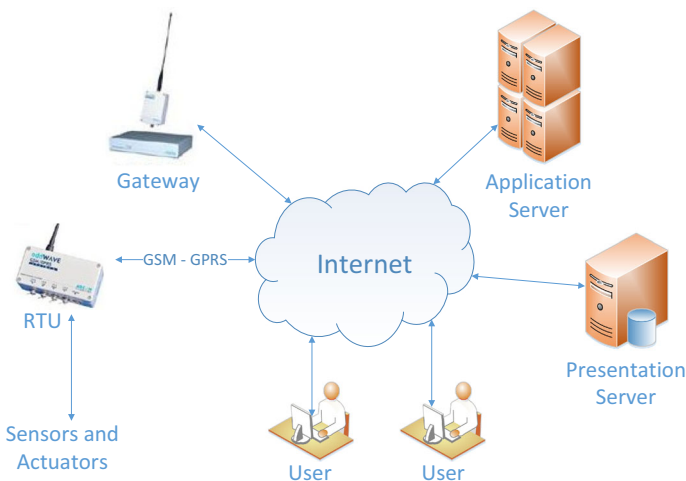


**Fig. 2** General structure of the tele-monitoring system

In the relatively few instances when this will be possible, the RTU-Gateway communication will be held by radio exclusively in the UHF band of 430–440 MHz. The system's key elements are:

- Gateway, which ensures the communication with the RTUs and available resource management;
- Presentation Server (PS) which is hosted on a computer with server features (for example, unattended operation 24/7), equipped with a software package focused mainly on data presentation in various forms, entirely available to users;
- Application Server (AS), focused on special tasks, which PS cannot perform.

Practically, all system communication is done through the Internet and this gives the system investment and mostly operational advantages. It is mentioned that the users can access the processed data, offered by the PS and AS anywhere and anytime, from any terminal with Internet access (PC, tablet, mobile phone etc.) [32].

The system's central elements are configured and scaled so that they would allow a system takeover of 100 RTUs.

## 4 Implementation of Hydro-Energy Telemetry System and Obtained Results

### 4.1 Installation Structure

In this chapter we present the particularities of the implementation for hydro-energy telemetry with respect to general implementations for aeolian or photovoltaic tele-monitoring. Similar applications could be identified for photovoltaic panels where voltage and current information is periodically sampled and transferred by M2M protocols. What is usually being used in measurement of energy potential and monitoring performances of photovoltaic parks is as follows: a remote telemetry unit, total radiation sensor pyranometer, sunshine duration sensor, albedometer, wind speed and wind direction sensor, air temperature and relative humidity sensor, barometric pressure sensor, solar panel for powering the M2M devices and sensors.

When the hydro power installation site to be monitored is a water intake installation, the structure of the installation that will be mounted at the site is shown in Fig. 3.

Components of this structure are:

- Remote Telemetry Unit (RTU), with GSM/GPRS communication in UHF band of 430–440 MHz;
- Solar panel which ensures power supply to RTU's and most of the sensor;
- Rain gauge;
- Interface boards PI and PI2;
- Sensors connected to RTU through PI and PI2;
- Electrovalve controlling the water intake in the segment-valve;
- Auxiliary battery of 24 V for the power supply of the electrovalve to control the water intake and some of the sensors.

Comparing the proposed implementation with existing ones, there are similarities regarding the use of RTUs and solar panel and obviously differences regarding the sensors connected to the RTU for specific energy monitoring. For Adcon A753 (GSM/GPRS) or

**Fig. 3** General structure of the water take telemetry solution
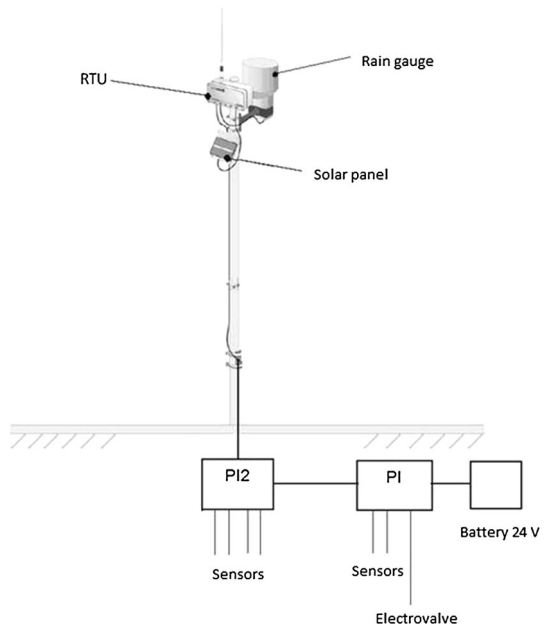
Adcon A733 (UHF) RTUs [9], for example, the interface board PI2 is connected through cables to I/O A, I/O C and I/O D ports. The rain gauge is connected to the RTU's I/O B port. Also, some of the sensors are connected to the PI2 board.

The interface board PI2 will be placed, usually in the mast base. The interface board PI connects the rest of the sensors through cables, the electrovalve which ensures the water intake control in the segment-valve, and also the auxiliary battery of 24 V.

The interface boards PI and PI2 are interconnected through a multicore cable, pulled through a protection tube. The tube and the cable inside must pass through the concrete wall of the segment-valve room and finally to reach the metallic mast.

The parameters that can be monitored and specific sensors at a water intake are presented in Table 1.

The monitored parameters at the water intake are represented by the flow captured in summer and winter period. For the flow captured in the summer period a probe of water level is used with a range of 0–150 cm, mounted in the tank inside a protection metal tube; in winter period a water level probe with a range of 0–10 m is used, mounted at the dam's base, with probe reference level under the lower threshold of the winter intake. Other parameters that need to be measured are the water level in the lake at the dam (to measure this parameter, the water level probes mentioned are used), the air temperature (this parameter is reported to the temperature sensor integrated in RTU A723, placed in the dam), rainfall level (to measure this parameter, the standard aluminium rain gauge is used, with a resolution of 0.2 mm, connected to RTU A723).

The parameters resulted by integration (summing) allow the possibility of calculating the water amount (in mc) captured in a given time period. Also, it is possible to find the rainfall amount (in mm = l/mp) captured in a given time period.

Each of the parameters from 1 to 11 in Table 1 is measured by RTU once every 3 min. Every 15 min, RTU will calculate a mean value of the five measurements performed in that

**Table 1** Monitored parameters and sensors used for water intakes

| | Parameter | Sensor type | Technical specification |
|---|---|---|---|
| 1 | Water level in lake | Water level sensor | Water level probe 0 … 10 m |
| 2 | Intaken flow | Water level sensor | Water level probe 0 … 1.5 m |
| 3 | Water's reference pressure in tank | Pressure cell horizontally mounted | Pressure cell 50 cm; 1 bar FS |
| 4 | Rainfall intensity | Pluviometer | Standard pluviometer, 200 $cm^2$, 0.2 mm |
| 5 | Air temperature (in A753, A733) | Temperature sensor | Internal sensor RTU A753, A733 |
| 6 | Segment-valve position | Inclinometer | Inclinometer + 10 grade; 4–20 mA |
| 7 | Wall valve position | Opening detector | Contact opening detector |
| 8 | Mast position | Opening detector | Contact opening detector |
| 9 | Voltage on RTU A753 battery | Voltmeter | Internal sensor RTU A753, A733 |
| 10 | Voltage on the auxiliary 24 V battery | Voltmeter | Voltage splitter |
| 11 | Command of the electrovalve | Actuators | MOSFET power transistors |
| | *Deduced parameters* | | |
| | Difference between total pressure and differential pressure | From parameters 1, 2 and 3 | |
| | Rainfall amount | From parameter 4 | |

interval. Every hour, RTU will send through the bridge RA440 to the Presentation Server the four mean values calculated for each parameter.

RTU will be able to keep the measured parameters for 10 days, in case the communication with the AS is unavailable.

The PS will keep available to users the primary and processed data during 2 years. In case it's considered useful, the period this data is kept could be longer than 2 years.

## 4.2 Measurement Results

Figures 4, 5 and 6 present measurement results for the evolution of two of the monitored parameters, considering the water level in a lake in the summer period and the flow captured in the summer period.

PS presents 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 the possibility of highlighting the average, the amount, the maximum and minimum registered value for each parameter for periods of time, on user's demand.

Figure 4 presents the measured parameters on the 15th March 2012, as the water intake was switched to the summer operating system. The water level in the reservoir, at the dam was 1.51 m, and the captured flow had small values, about 2400 $m^3$/h [33].

At the end of May 2012, the level in the reservoir and the captured flow stabled around 1.80 m and 21,000 $m^3$/h. Important deviations were noticed only during intense rain, like the one in 31.05.2012, as seen in Fig. 5.
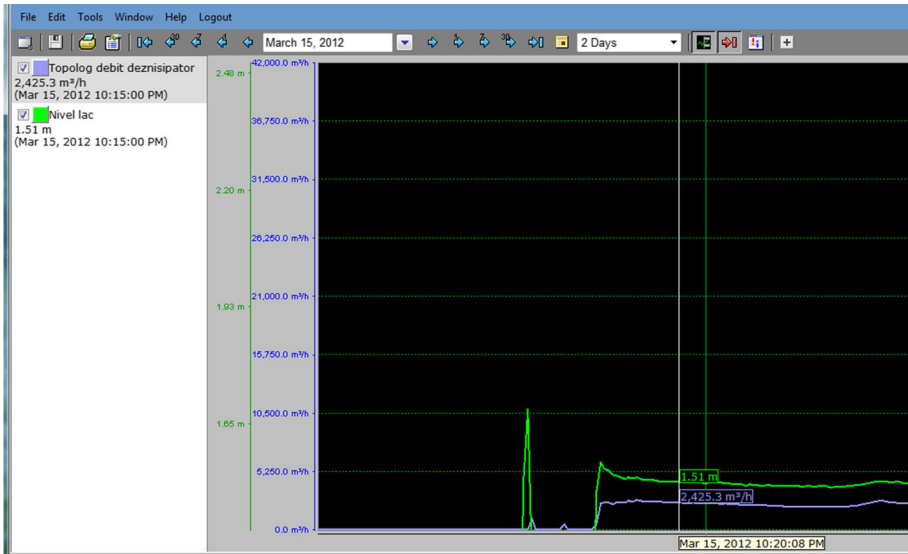
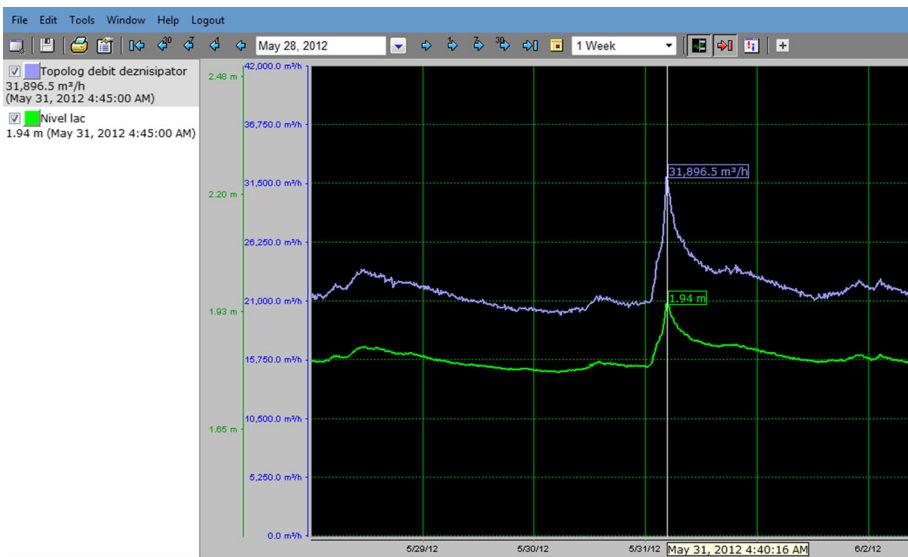**Fig. 4** Summer operating switchover



**Fig. 5** Deviation of parameters during intense rain

Because of the extended drought, in September 2012, both the level in lake and the captured flow are stable, unfortunately at low levels (captured flow 2860 m³/h). On 11.09.2012, the water capture process was interrupted for about 8 h, as presented in Fig. 6.

The main challenge posed by the presented application to a M2M cloud implementation was the energy efficiency of the sensors and RTUs, especially during periods when the
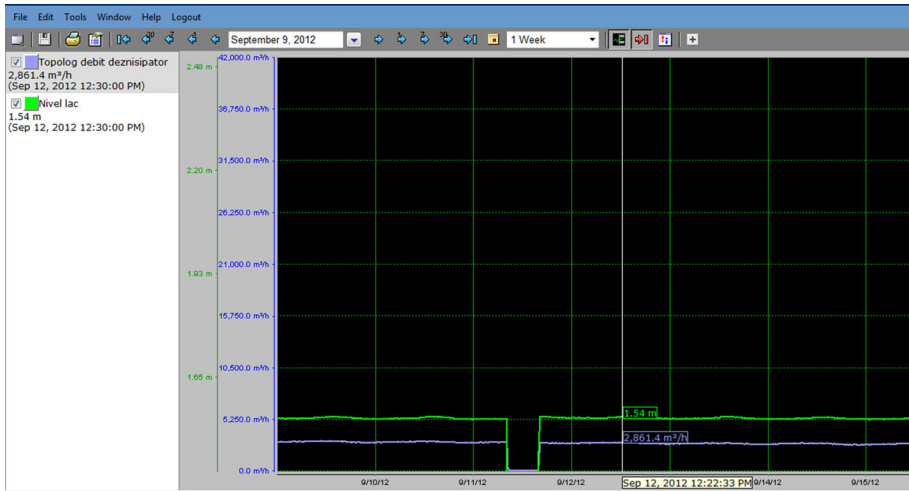
**Fig. 6** Deviation of parameters during water capture interruption

battery was not charged due to the lack of solar radiation. Consequently, in order to have near-real time relevant results, we improved the system by optimizing the data sampling rate and sending average values as presented in Sect. 4.1. Finally, the results were compared with on-site manual measurements and small adjustments were done so that the measurement results could be compared with similar results [34] existing in the literature. The implementation demonstrated that it performs better than using other sensors such as radars, sonar or infrared and the cloud platform provided elastic resources for storing and processing of the big data volumes, offering advantages such as live migrations compared to traditional approaches.

## 5 Conclusions and Future Directions

The present paper discussed a number of popular ICT paradigms, including Cloud computing, IoT and Big Data. It provided an extensive state-of-the-art review of them and the convergence between them. Next, the paper analyzed a proposed M2M telemetry system based on a decentralized cloud architecture, general systems and Remote Telemetry Units (RTUs), for renewable energy objectives tele-monitoring. The system was built for Big Data processing of sensors information in the way that data can be aggregated to generate "virtual" sensors, and some measurement results were presented.

With the advent of smart mobile devices, the Internet access has become ubiquitous, and has opened the way for new applications that use M2M communications. Indeed, the Internet of Things paradigm is an evolution of the traditional Internet for seamlessly integrating most things around us and collecting big data from sensors that track everything happening in our environment. IoT is already a reality and is growing, while the way we apply this new concept will drive new applications and may revolutionize life. Future research includes concepts such as flexible, open, and standardized service interfaces—Internet of Services (IoS), people becoming part of ubiquitous intelligent networks having the potential to seamlessly exchange information—Internet of People (IoP), and, finally,

the ability to interconnect any web enabled device and provide natural Human-2-Machine (H2M) interaction interfaces—Internet of Everything (IoE).

# References

1. Vermesan, O., Friess, P., Guillemin, P., Gusmeroli, S., et al. (2011). Internet of things strategic research agenda. In O. Vermesan & P. Friess (Eds.), *Internet of things—global technological and societal trends*. Aalborg: River Publishers.
2. Suciu, G., Vulpe, A., Halunga, S., Fratu, O., Todoran, G., & Suciu, V. (2013). Smart cities built on resilient cloud computing and secure internet of things. In *19th international conference on control systems and computer science (CSCS), IEEE*, pp. 513–518.
3. McFedries, P. (2008). The cloud is the computer. *IEEE Spectrum*. http://spectrum.ieee.org/computing/ hardware/the-cloud-is-the-computer. Accessed December 2014.
4. Lim, H. B., et al. (2005). Sensor grid: Integration of wireless sensor networks and the grid. In *Proceedings of IEEE conference local computer networking*.
5. Hassan, M. M., Song, B., & Huh, E. N. (2009). A framework of sensor-cloud integration opportunities and challenges. In *Proceedings of international conference ubiquitous information management communication*, pp. 618–626.
6. Fox, G. (2012). Clouds and the Internet of things (sensor clouds). http://grids.ucs.indiana.edu/ ptliupages/publications/SensorCloudsWhitePaper.pdf. Accessed 24 July 2013.
7. Open Source IoT Cloud. https://sites.google.com/site/opensourceiotcloud. Accessed December 2014.
8. Open Source Solution for the Internet of Things into the Cloud. http://www.openiot.eu. Accessed December 2014.
9. Xively—Public Cloud for the Internet of Things. https://www.xively.com. Accessed December 2014.
10. Internet of Things—ThingSpeak. https://www.thingspeak.com. Accessed December 2014.
11. Sensor Cloud. http://www.sensor-cloud.com. Accessed December 2014.
12. Kranz, M., Holleis, P., & Schmidt, A. (2010). Embedded interaction: Interacting with the Internet of things. *IEEE Internet Computing*. doi:10.1109/MIC.2009.141
13. RADICAL: RApid Deployment and adoption of sustainable socially-aware and intelligent sensing services for emerging smart cities. ICT-PSP project. http://ec.europa.eu/information_society/apps/ projects/factsheet/index.cfm?project_ref=325138. Accessed December 2014.
14. SmartSantander. FP7 project. http://www.smartsantander.eu. Accessed December 2014.
15. Tan, S. K., Sooriyabandara, M., & Fan, Z. (2011). M2M communications in the smart grid: Applications, standards, enabling technologies, and research challenges. *International Journal of Digital Multimedia Broadcasting*, 2011, 1–8.
16. Fan, Z., Haines, R. J., & Kulkarni, P. (2013). M2M communications for E-health and smart grid: An industry and standard perspective. arXiv preprint arXiv:1306.3323.
17. Zhou, H. (2012). *The internet of things in the cloud: A middleware perspective*. Boca Raton: CRC Press.
18. Fan, Z., Chen, Q., Kalogridis, G., Tan, S., & Kaleshi, D. (2012). The power of data: Data analytics for M2M and smart grid. Innovative Smart Grid Technologies (ISGT Europe), 2012 3rd IEEE PES international conference and exhibition on (pp. 1–8). IEEE.
19. Yigit, M., Gungor, V. C., & Baktir, S. (2014). Cloud computing for smart grid applications. *Computer Networks, 70*, 312–329.
20. Karim, L., Anpalagan, A., Nasser, N., & Almhana, J. (2013). Sensor-based M2M agriculture monitoring systems for developing countries: State and challenges. *Network Protocols and Algorithms, 5*(3), 68–86.
21. Seo, J. W., Moon, S., Jang, J. H., & Park, J. H. (2013). Stand-alone operation with a centralized controller for multiple PV module converters. In *IEEE power electronics and drive systems (PEDS), 2013 IEEE 10th international conference on* (pp. 1335–1337).
22. FP7 Work Programme 2013. Cooperation Theme 3: ICT (2012). http://ec.europa.eu/research/ participants/portalplus/static/docs/calls/fp7/common/32767-annex_6_to_the_decision_ict_for_cap_en. pdf. Accessed December 2014.

23. FP7 Work Programme 2013. Cooperation Theme 5: Energy. (2012). http://ec.europa.eu/research/participants/portalplus/static/docs/calls/fp7/common/32765-annex_8_to_the_decision_energy_for_cap_en.pdf. Accessed December 2014.

24. Exploiting Big Data: Strategies for Integrating with Hadoop to Deliver Business Insights (2012). http://media.techtarget.com/digitalguide/images/Misc/EA-Marketing/E-Zine/BAA%20assets/BigDataReport_final.pdf. Accessed December 2014.

25. McAfee, A., & Brynjolfsson, E. (2012). Big data: The management revolution. http://hbr.org/2012/10/big-data-the-management-revolution. Accessed December 2014.

26. Gartner Says Worldwide Cloud Services Market to Surpass $109 Billion in 2012. (2012). http://www.gartner.com/newsroom/id/2163616. Accessed December 2014.

27. Hung, S. H., Chen, C. H., & Tu, C. H. (2012). Performance evaluation of machine-to-machine (M2M) systems with virtual machines. *International Symposium Wireless Personal Multimedia Communications, 15*, 159–163.

28. Suciu, G., Cernat, C., Todoran, G., Suciu, G., Poenaru, V., Militaru, T., & Halunga, S. (2012). A solution for implementing resilience in open source Cloud platforms. *International Conference on Communications, 9*, 335–338.

29. Tsai, S. Y., Sou, S. I., & Tsai, M. H. (2012). Effect of data aggregation in M2M networks. *International Symposium Wireless Personal Multimedia Communications, 15*, 95–99.

30. Kumar, S. G., & Buyya, R. (2011). *Green cloud computing and environmental sustainability*. http://www.cloudbus.org/papers/Cloud-EnvSustainability2011.pdf. Accessed December 2014.

31. Greenpeace International. (2010). Make IT green: Cloud computing and its contribution to climate change. http://www.greenpeace.org/international/en/publications/reports/make-it-green-Cloudcomputing. Accessed December 2014.

32. Ochian, A., Suciu, G., Fratu, O., & Suciu, V. (2014). Big data search for environmental telemetry. *Communications and networking (BlackSeaCom), IEEE international Black Sea conference on*, pp. 182–184.

33. Suciu, G., Halunga, S., Fratu, O., Vasilescu, A., & Suciu, V. (2013). Study for renewable energy telemetry using a decentralized cloud M2M system. In *Wireless personal multimedia communications (WPMC), IEEE 15th international symposium on*, 24–28 Jun. 2013, pp. 1–5.

34. Fahle, M., Dietrich, O., & Lischeid, G. (2013). A guideline for developing an initial hydrological monitoring network as a basis for water management in artificially drained wetlands. *Irrigation and Drainage, 62*(4), 524–536.
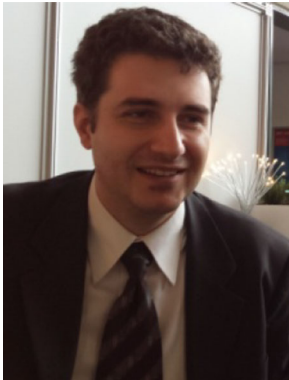
**George Suciu** graduated from the Faculty of Electronics, Telecommunications and Information Technology at the University POLITEHNICA of Bucharest, where he received also his M.Sc. and Ph.D. He holds a Master diploma in Informatics Project Management from the Faculty of Cybernetics, Statistics and Economic Informatics of the Academy of Economic Studies Bucharest, and currently, his post-doc research work is focused on the field of cloud communications, big data and IoT/M2M. Also, he is IEEE member and has received a type D IPMA certification in project management from Romanian Project Management Association/IPMA partner organization. He is the author or co-author of over 60 journal articles and scientific papers presented at various international conferences. His scientific fields of interest include: project management, electronics and telecommunication, cloud computing, data acquisition and signal processing. Known languages: German, French, English; He has also experience in project leading and participation in various research projects (FP7, National Structural Funds, Eureka, H2020), with more than 20 years activity in information and telecommunication systems. He is managing ongoing R&D projects such as ACCELERATE and SWITCH which will serve to industrialize the cloud communications solutions. George Suciu occupies since 2008 the position of IT&C Solutions Manager—R&D Department, being employed since 1998 at BEIA Consult International, a research performing SME and one of the main suppliers for telecommunication equipment and ITC business services in Romania, with an experience since 1991 in more than 5000 projects.

**Alexandru Vulpe** received the Ph.D. degree in Electronics, Telecommunications and Information Technology from the University POLITEHNICA of Bucharest, Romania in 2014. His research interests include, among others, Mobile Communications, Wireless Sensor Networks, Quality-of-Service, Radio Resource Management, Mobile Applications. His publications include more than 30 papers published in journals or presented at international conferences. He participated as a researcher in a number of national or international projects such as "Reconfigurable Interoperability of Wireless Communications Systems (RIWCoS)", NATO Science for Peace Research project (2007–2010), "Wireless Hybrid Access System with Unique Addressing (SAWHAU)", Romanian "Partnerships in priority fields" research project (2008–2011) "eWALL—eWall for Active Long Living" (FP7 project, 2013–2016), "Optimization and Rational Use of Wireless Communication Bands (ORCA)", NATO Science for Peace project (2013–2015).

**Alexandru Martian** received his B.Sc. and Ph.D. from POLITEHNICA University of Bucharest in 2000 and 2013, respectively. From 2000 to 2007 he worked in the field of telecommunication systems in Germany and Romania. Since 2007 he has been with the POLITEHNICA University of Bucharest where he currently works as a lecturer. As a part of his Ph.D. thesis he conducted several measurement campaigns for evaluating the spectrum occupancy in Romania and used the USRP software defined radio platform for implementing applications in the spectrum sensing area. His current research interests reside in the area of Mobile Radio Communication Systems, with an emphasis on Dynamic Spectrum Access, Software Defined Radio and Cognitive Radio. His current post-doctoral research is focused on Spectrum Sensing Systems for Cognitive Radio Equipment. He was actively involved in several national and international research projects such as "Cognitive Radio Technology and the efficient use of RF spectrum", "Scalable Radio Transceiver for Instrumental Wireless Sensor Networks (SaRaT-IWSN)" and "eWALL— eWall for Active Long Living" (FP7 project, 2013–2016).

**Simona Halunga** received the M.S. degree in electronics and telecommunications in 1988 and the Ph.D. degree in communications from the University POLITEHNICA of Bucharest, Bucharest, Romania, in 1996. Between 1996–1997 she followed post-graduate courses in Management and Marketing, organized by the Romanian Trade and Industry Chamber and Politehnica University of Bucharest, in collaboration with Technical Hochschule Darmstadt, Germany, and in 2008—post-graduate courses in Project Management—Regional Centre for Continuous Education for Public Local Administration, Bucharest She has been Assistant Professor (1991–1996), Lecturer (1997–2001), Associate Professor (2001–2005) and from 2006 she is a full professor at in Politehnica University of Bucharest, Electronics, Telecommunications and Information Theory Faculty, Telecommunications Department. Between 1997–1999 she has been a Visiting Assistant Professor at Electrical and Computer Engineering Department, University of Colorado at Colorado Springs, USA. Her domain of interest are Multiple Access Systems & Techniques, Satellite Communications, Digital Signal Processing for Telecommunication, Digital Communications-Radio Data Transmissions, Analog and Digital Transmission Systems and Digital Signal Processing for Telecommunications.

**Dragos Nicolae Vizireanu** is Professor at Telecommunications Department, Faculty of Electronics, Telecommunications and Informations Technology from University Politehnica of Bucharest, Romania. He is Master of Science in Electrical Engineering (MSEE) (1995) from Georgia Institute of Technology, School of Electrical and Computer Engineering, Atlanta, Georgia, USA and Ph.D. (1998) from University Politehnica of Bucharest, Faculty of Electronics, Telecommunications and Informations Technology. His research interests and teaching activities are: digital communications, instrumentations and measurements, signal, image/video processing and communications. He published more de 12 books and is author or coauthor of more than 150 papers in international journals and conferences. His research interests include: digital communications, instrumentations and measurements, signal, image/video processing.