

## CLOUD M2M PLATFORM FOR RENEWABLE ENERGY TELE-MONITORING

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*The purpose of this paper is to define and describe a cloud M2M (Machine 2 Machine) platform, that is used for tele-monitoring renewable energy sources, with a specific focus on hydro-energy. We will present findings related to cloud architecture and resource management used for M2M systems, with the goal to assess the level of efficiency and security offered by these technologies. The paper fills a gap in the existing critical infrastructure literature, by providing a case study of cloud M2M platform reference model, which could be used in other tele-monitoring applications.*

**Keywords:** cloud, M2M, tele-monitoring, renewable energy

### 1. Introduction

Recent research in cloud computing has focused on how to efficiently use the existing power of computer and telecommunication networks for big data processing in various applications fields [1].

Such applications include using distributed cloud platforms for processing heterogeneous data from multi-disciplinary scientific research, such as mining sensors information used for agriculture [2] or environmental monitoring [3].

In the energy domain, competitive prices and rising costs of production are forcing producers to optimize costs and to introduce the smart grid paradigm, and therefore performing simulations on cloud computing systems [4]. The growing environmental awareness of consumers further accelerates this process and promotes the usage of renewable energy sources in data centres [5].

In their vast majority, solar and aeolian energy resources are exploited by using recently manufactured systems, which have built-in tele-monitoring equipment, as an important part of the whole investment. The situation is different in the case of hydro-energy power plants, which are built since over 50 years, with constant efforts for automation and information, focused mostly on the turbines. Only recently the problems of tele-monitoring the external environment, such as water incomes, main and secondary water intakes and even hydrographical basin,

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were addressed. Furthermore, this is an important topic that needs to be addressed, as water becomes an even more problematic and scarce resource, which hydro-energy needs to share and coordinate with other domains, such as environmental protection and agriculture.

On the other side, there is little evidence in the existing literature about remote automatic monitoring system for field information from renewable energy sources, 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 [6].

In previous approaches RTUs (Remote Terminal Units) were implemented in most cases by deploying general use components and sensors on a local server, and no company could aggregate enough sensor data to consider automating the production process and providing the required resilience [7]. Furthermore, by using low power sensors and data aggregation the energy consumption of the M2M network can be optimized [8].

In this paper we present a cloud test platform for clean energy production telemetry, with focus on hydro-energy. We use different types of RTU's and sensors that monitor and transmit important information from selected locations such as temperature, precipitation, water level in the dam and quantity of water captured during winter or summer. On our cloud testing environment we provide the platform for processing information from hundreds of different sensors, enabling the analysis of environmental data through a large sample of RTUs.

The paper is structured as follows: Chapter 2 describes the cloud M2M architecture of the proposed tele-monitoring platform. In Chapter 3 we present the measurement methodology and results obtained so far. The conclusion summarizes the novel contributions and envisions future work.

## **2. Cloud M2M architecture**

We will base our architecture on SlapOS [9], the first open source operating system for Decentralized Cloud Computing. SLAP stands for "Simple Language for Accounting and Provisioning". SlapOS is based on a grid computing daemon called slapgrid which is capable of installing any software on a PC and instantiate any number of processes of potentially infinite duration of any installed software. Slapgrid daemon receives requests from a central scheduler the SlapOS Master which collects back accounting information from each process.

SlapOS is an open source Cloud Operating system which was inspired by recent research in Grid Computing and in particular by Bonjour Grid [10], a meta Desktop Grid middleware for the coordination of multiple instances of Desktop Grid middleware. It is based on the motto that "everything is a process". SlapOS

Master follow an Enterprise Resource Planning (ERP) model to handle at the same time process allocation optimization and billing.

This structure has been implemented for cloud-based automation of ERP and CRM software for small businesses and aspects are under development under the framework of the European research project “Cloud Consulting” [11]. We will use our platform hosted on several servers running Ubuntu Linux – Apache – MySQL template with current software release.

SlapOS is based on a Master and Slave design, as shown in Fig. 1. Based on this architecture we 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.

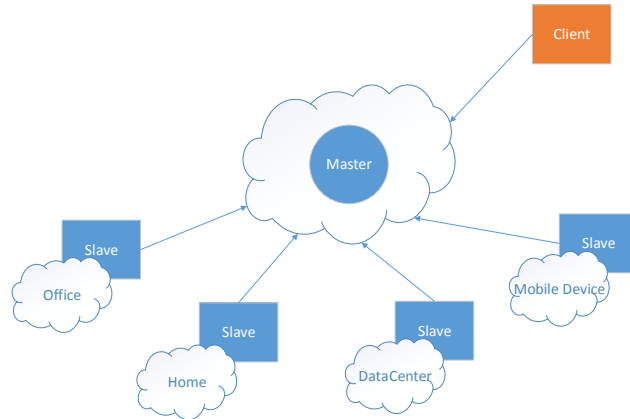


Fig. 1. SlapOS Master – Slave Cloud Architecture

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 to 500 computer partitions.

The tele-monitoring system will have a hierarchical pyramidal structure, on the base having sensors for measuring the specific parameters, connected to RTUs. Each RTU connects to a gateway, usually via radio link, for transmitting the data. On top of the pyramid is a cloud service, which receives the primary data from the gateways and delivers processed data, in the form of reports and alarms for various users of the system. Furthermore, users can issue actuating commands that are sent back to the tele-monitored systems.

In Fig. 2 we present the general structure of the M2M system that we propose for the tele-monitoring of installation sites in hydro power stations.

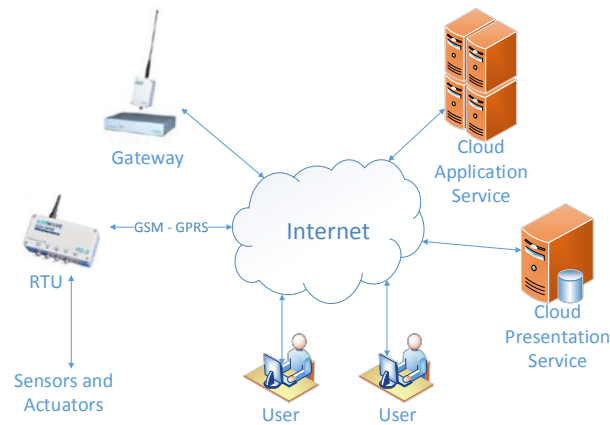


Fig. 2. General structure of the tele-monitoring system

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 data concentrator through a bridge station (bridge) which will ensure the UHF-GPRS and GPRS-UHF conversion.

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;
- Cloud Presentation Service (CPS) 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.

- Cloud Application Service (CAS), focused on special tasks, which CPS cannot perform.

### 3. Measurement Methodology and Results

For a hydro power installation site to be monitored, the parameters that can be monitored and specific sensors at a water intake are presented in Table 1.

Table 1

**Monitored parameters and sensors for a water intake**

	<i>Parameter</i>	<i>Sensor type</i>	<i>Technical Specification</i>
1	Water level in lake	Water level sensor	Water level probe 0 ...10 m
2	Intake 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 cmp, 0,2 mm
5	Air temperature	Temperature sensor	Internal sensor RTU
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 battery	Voltmeter	Internal sensor RTU
10	Voltage on the auxiliary 24 V battery	Voltmeter	Voltage splitter
11	Command of the electro valve	Actuators	MOSFET power transistors
	<b>Deduced parameters</b>		
	Difference between total pressure and differential pressure	From parameters 1, 2 and 3	
	Rainfall amount	From parameter 4	

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 meters 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, 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).

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 three minutes. Every fifteen minutes, RTU will calculate a mean value of the five measurements performed in that interval. Every hour, RTU will send through the bridge 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 CAS is unavailable.

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

CPS presents the measured data as a table or in the diagram form. There are multiple possibilities for visualizing the data on 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 to highlight the average, the amount, the maximum and minimum registered value for each parameter for periods of time, on user's demand.

In Fig. 3 we present the measured parameters on the 15th March 2012, as the water intake was switched to the summer operating system. The water level in the accumulation lake, at the dam was 1,51 m, and the captured flow had small values, about 2.400 mc/h.

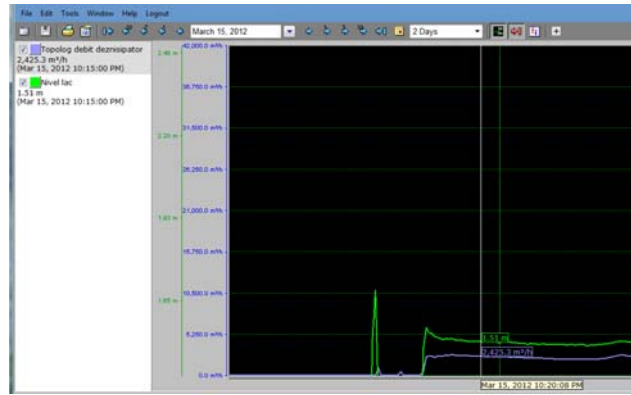


Fig. 3. Summer operating switchover

At the end of the May 2012, the level in the accumulation lake and the captured flow stabilized around 1.80 meters and 21.000 mc/h. Important deviations were noticed only during intense rain, like the one in 31.05.2012, as seen in Fig. 5.

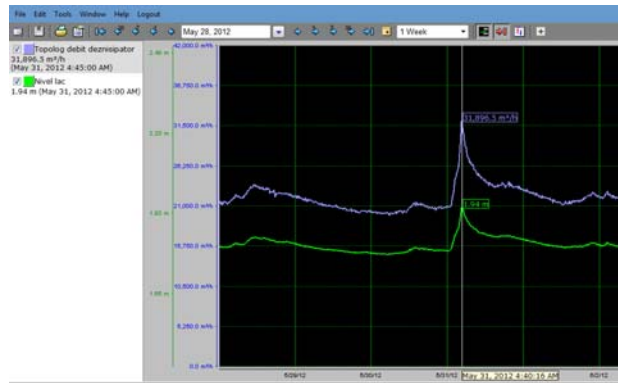


Fig. 5. Deviation of parameters during intense rain

#### 4. Conclusions

The paper proposed a decentralized M2M cloud platform for tele-monitoring the production of renewable energy sources and presented the methodology of measurement applicable for hydro-energy.

We presented measurement results at a water intake to demonstrate that our methodology produces relevant results, and that the cloud system provides a reliable platform for storing, processing and visualization of the data.

As future work, we envision to extend our system for tele-monitoring of new innovative energy sources, including photovoltaic and aeolian applications.

## REFERENCES

- [1] *D. Agrawal, D. Sudipto, and A. El Abbadi*, "Big data and cloud computing: current state and future opportunities." In Proceedings of the 14th International Conference on Extending Database Technology, pp. 530-533. ACM, 2011
- [2] *G. Suci, O. Fratu, V. Poenaru, et.al.* "Cloud systems for environmental telemetry - A case study for ecological monitoring in agriculture", XLVII International Scientific Conference on Information, Communication and Energy Systems and Technologies, ICEST 2012, Proceedings of Papers, Vol. 1, pp. 273-276, 2012.
- [3] *M. Rodriguez-Martinez, J. Seguel, and M. Greer*, "Open source cloud computing tools: A case study with a weather application" 3rd International Conference on Cloud Computing (CLOUD), pp. 443-449, IEEE, 2010.
- [4] *S. Rusitschka, K. Eger, and C. Gerdes*, "Smart grid data cloud: A model for utilizing cloud computing in the smart grid domain" First IEEE International Conference on Smart Grid Communications (SmartGridComm), pp. 483-488, IEEE, 2010.
- [5] *A. H. Mohsenian-Rad and A. Leon-Garcia*, "Energy-information transmission tradeoff in green cloud computing" Carbon, pp. 200-206, IEEE, 2010.
- [6] *S.H. Hung, C.H. Chen, and C.H. Tu*, "Performance evaluation of machine-to-machine (M2M) systems with virtual machines," 15th International Symposium on Wireless Personal Multimedia Communications (WPMC), pp.159-163, 2012.
- [7] *G.Suci, C. Cernat, G. Todoran, et.al.*, "A solution for implementing resilience in open source Cloud platforms," 9th International Conference on Communications (COMM), pp.335-338, IEEE, 2012.
- [8] *S.Y. Tsai, S.I. Sou, and M. H. Tsai*, "Effect of data aggregation in M2M networks," 15th International Symposium on Wireless Personal Multimedia Communications (WPMC), pp.95-99, 2012.
- [9] *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, 2011.
- [10] *H. Abbes, C. Cerin, and M. Jemni*, "Bonjourgrid: Orchestration of multi-instances of grid middlewares on institutional desktop grids." International Symposium on Parallel & Distributed Processing (IPDPS), pp. 1-8. IEEE, 2009.
- [11] *G. Suci, O. Fratu, S. Halunga, et.al.* "Cloud consulting: ERP and communication application integration in open source cloud systems." In Telecommunications Forum (TELFOR), 2011 19th, pp. 578-581. IEEE, 2011.