

An IoT business environment for Multi Objective Cloud Computing Sustainability Assessment Framework

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Abstract— The aim of this paper is to highlight the potentials of the Internet of things (IoT) in supporting sustainable economical, ecological, social and especially business growth, according to the Multi-Objective (MO) Cloud Computing (CC) Sustainability assessment model. IoT is highly related to the CC as its inherent environment and platform for the operations. It has motivated us to present the ways of harnessing IoT capacities in realization of the defined sustainable development goals (SDGs), aiming to bring sustainable development, taking care of the present needs but without jeopardizing the ability of next generations to meet their own necessities. The MO CC Sustainability Assessment Framework is perfectly matched with IoT paradigm, taking a rule of support platform for storage and analysis of data collected from the IoT networked devices. Our idea is to provide a wide sustainability assessment framework that will encompass all the diversity of design and use variations as well as the integration of the CC technology as a support platform for more specific environments and architectural designs.

I. INTRODUCTION

Cloud Computing (CC) is one of the most potential transformative paradigms in business and society areas, delivering a spectrum of computing services and various usage alternatives to the customers. As such, CC has recently triggered additional attention and efforts towards searching its sustainability conformance side and proposing a proper sustainability assessing model. The existing literature indicates that there were certain efforts to provide some modeling, but unfortunately there is no comprehensive proposal. We have proposed Multi Objective Cloud Computing Sustainability Assessment framework that is based on four different pillars, or specific areas that cloud computing technologies and its development strategies have strong influence to [1, 2]. It is a Multi-Objective (MO) model designed with a goal to analyze the effects of CC technologies at the economy, business, ecology, and society levels. The framework is designed with a goal to free the users from defined constraints when choosing relevant objectives for their system/working environment. Such high level of flexibility allows the design and joint use of CC and Internet of Things (IoT) paradigms. The driving motivation for this paper is to provide an analysis of the IoT technology potentials that would support sustainable

economical, ecological, social and business growth, according to the MO CC Sustainability Assessment Framework. CC is an environment which facilitates IoT functioning, as it supports handling the high data volumes generated from large number of devices, conserves energy, memory, processing and minimizes the costs.

II. MOTIVATION FOR RESEARCH

The increasingly rapid developing and greatly consumerist human life environment implicates that the natural resources are also increasingly consumed with time. Furthermore, the way of using the resources is rapidly changing, thus the issue of ensuring the needed level of sustainability becomes one of the most important research questions [3]. The MO CC Sustainability Assessment Framework is perfectly matched with IoT paradigm, as Cloud has become an ultimate support platform for storage and analysis of data collected from the IoT devices, allowing smooth utilization of the applications that rely on the virtualization technologies and intensive data computation.

There is an arising interest in merging Cloud and IoT, as their joint use has become pervasive, making them inevitable components of the Future Internet. The research question stated for this study is how to provide a sustainability assessment framework that will encompass all the diversity of design and use of IoT, as well as the integration of the CC technology as a support platform for specific environments, data and architectural designs.

III. RELATED WORK

Even though there were some initiatives to provide a suitable sustainability assessment approach, the work related to the sustainability in IoTs based on CC still lacks the integrated proposal. The existing models mostly direct the attention to one specific sustainability pillar. For instance, a group of authors has addressed the most prominent business models for long-term sustainability, Cloud Cube Model (CCM) and Hexagon model [4]. There are studies that are oriented towards the models focused to the financial aspect, such as the Capital Asset Pricing Model (CAPM) [5]. The research for more comprehensive studies leads to the United Nations (UN) general model, which relies on 10 principles and 17 sustainability development goals (SDGs) for stable sustainability development modeling [6, 7]. Our methodology strongly

relies on the UN directions, while further expanding the proposed MO CC Sustainability assessment model [1, 2] with business area based aspects that are highly related to the proper application and use of the IoT technologies. For analysis and comparison to the UN model, we have taken into consideration the UN SDGs.

IV. IOT-CLOUD COMPUTING MO SUSTAINABILITY FRAMEWORK

The contributions of this paper are as follows: (1) We propose an MO CC Sustainability Assessment Framework with a focus to the business sustainability pillar, taking into consideration its matching capabilities with the IoT paradigm; (2) We formulate the set of the business oriented goals, taking into consideration the critical issues of meeting to the strict IoT latency requirements while transferring the data from devices/sensors to the cloud infrastructure, processing, providing adequate response, and keeping with high reliability.

Actually, it is a perfect moment to discuss this subject, considering the demand for the generation of the set of the recommendations that would form part of the Developing Innovation and Growing the Internet of Things Act (DIGIT Act), along with the White House's Smart Cities Initiative, that provides path to the enabling the urban environment for IoT deployment, while assuring environmental sustainability and Internet of Things Global Standards Initiative that has established Study Group 20 on "IoT and its applications including smart cities and communities" [8, 9]. DIGIT Act should be ready till the end of the 2017 and it should express "the sense of Congress that policies governing the IoT should maximize the potential and development of the growing number of connected and interconnected devices to benefit businesses, governments, and consumers". Thus, the overall sustainability enforcement should be a part of the procedures and policies to define.

Multi-objectivity has been recognized as a promising approach for a complex structures such the sustainability assessment for certain technology or system. So far this issue was not in the high focus of the community, but recently the need for green approach to almost all areas of human life has risen, giving certain precedence over many other topics. The most advantageous existing model is the UN model that treats the economy, ecology and social areas as the pillars for accessing the sustainability. Our model additionally analyzes the business area as the fourth pillar. The four discussed categories form the first layer of models' hierarchy. The hierarchical structure of the model is given in Fig. 1. Our solution focuses to an analysis of the details related to the integration of the business part to the MO framework, considering IoT perspective. This idea has emerged as a natural consequence of the high IoT dependability on the fulfillment of the business aspects defined in MO model. Figure 2 presents an example of the provider Infrastructure as a Service (IaaS) IoT CC concept (applicable to all CC concepts), where the income domain profoundly estimates the business practices of the

infrastructure provider when applied to IoT, and puts light to the possibilities of using CC infrastructure.

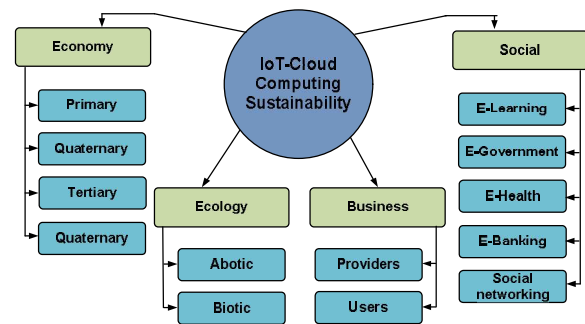


Figure 1. IoT-Cloud concept of the MO Sustainability Framework

Cloud Computing platforms represent shared and configurable computing resources that are provided to the user and released back with minimum efforts and costs. CC as a service can be offered in a form of: Infrastructure as a Service (IaaS); Platform as a Service (PaaS), Software as a Service (SaaS), and Data as a Service (DaaS) which is shifted forward to conceptually more flexible variation - Network as a Service (NaaS).

The technological improvement has yielded the extensive transition from the traditional desktop computing realm to the all-embracing use of the CC architectural and service provisioning pattern. It has further made basis for environment characterizes by favorable conditions for efficient movement of the services to the virtual storage and processing platforms, mostly offered through different CC solutions.

Internet of Things (IoT) are usually built from self configuring intelligent network devices, mostly mobile devices, sensors, and actuators.

As such, this environment is highly vulnerable and deals with a range of security/privacy concerns. It still lacks ideal energy efficiency solutions, and requires special efforts for guaranteeing reliability, performance, storage management, processing capacities.

One of the most actual topics is reflected through demanding IoT environment. It gives light to CC and IoT technologies, as IoT needs a strong support of the CC platforms, that can bring flourishing performances for a potentially vast number of interconnected heterogeneous devices [10].

CC is perfectly matched with IoT paradigm, taking a rule of support platform for storage and analysis of data collected from the IoT networked devices. Moreover, it is perfect moment to discuss and include to the proposed sustainability framework the arising interest in merging Cloud and IoT, in literature already named as "CloudIoT" or "IoT-Cloud" as their joint implementation and use has already become pervasive, making them inevitable components of the Future Internet.

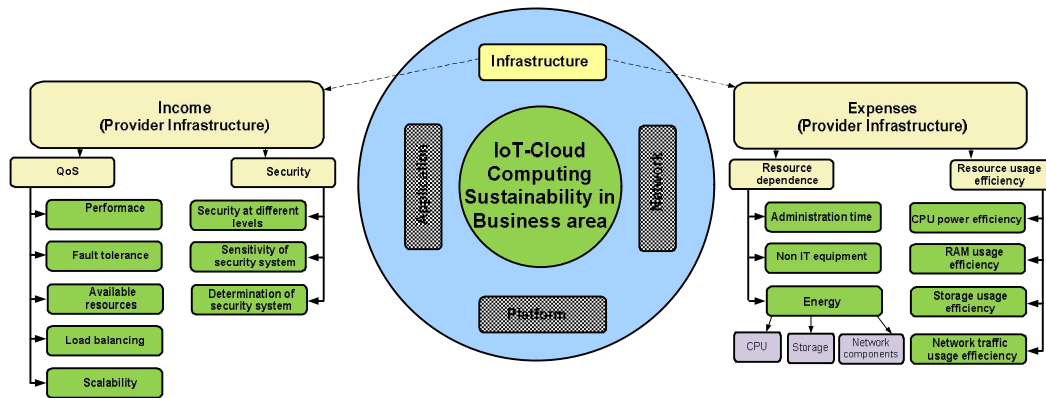


Figure 2. IaaS IoT-Cloud concept of the MO Sustainability Framework

Our idea is to provide a wide sustainability assessment framework that will encompass all the diversity of design and use variations as well as the integration of the CC technology as a support platform for more specific environments and architectural designs.

The merging of CC and IoT has further provided the possibility of pervasive ubiquitous distributed networking of a range of different devices, service isolation and efficient storage and CPU use. IoT practically represents the interconnection of the self configuring, smart nodes, so called "things", and allows: fast and secure exchange of different data formats; data processing and storage; building of the perfect ambient for raising popularity of IoT alike environments.

IoT has gained significant effect in building intelligent work/home scenarios, giving valuable assistance in living, smarter e-government, e-learning, e-health, e-pay services and range of transportation, industrial automation, and logistics. Figure 3 depicts the IoT and CC relationship.

For smoother explanation of this technological merging, the CC concept can be described as a complex I/O architecture. The input interface gathers diverse sources of Open and private data, which can be provided in a range of formats [11]. At the other side, the stored data is further processed, and in different forms (including the form of semantic WEB) offered as an output data sources. Besides offering a range of input and output interfaces, CC has to provide adequately designed middleware layer.

This layer is specific as it is a form of the abstraction of the functionalities and communication features of the devices. It has to bring efficient control and provide accurate addressing schemes. The services should follow these tendencies and allow the omnipresent and efficient computing performances. The goal is to keep the proper level of performances for IoT sensor/mobile/intelligent transport network in the sense of the uniqueness, persistence, reliability, and scalability. The NaaS CC concept, enforced with virtually unlimited memory and processing capabilities represents a basis to the IoT needs, strongly converging to the Things as a Service (TaS) concept. The drivers for the integration of these two concept are producing valuable impact to the development of different areas of research, industry and human life.

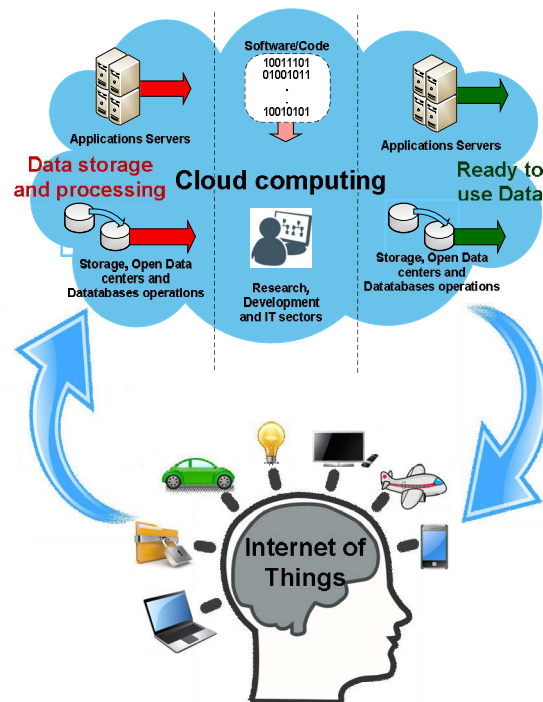


Figure 3. Cloud Computing and Internet of Things relationship.

The progress is obvious in the areas of corporative activities, financial activities, environmental care activities, health care activities, and in social networking, but there is still room for improvement and further enhancement of human life. As a consequence of the agreed directions for development in various industrial areas, new CC branches have appeared, mostly related to the design of Cyber Physical CC (CPCC), Mobile (personal or business) CC (MCC), Vehicular CC (VCC). All these areas can be further enhanced by introduction of the free use of open data and public data in combination with privately held data. Open Data initiatives are aimed at achieving available data for every one, and should be enabled to be combined with data from various sources. Open Data economy and the emerging initiative for its implementation stand for strong basis for business area development [11].

As IoT gathers a range of different devices, with specific interfaces, communication practices, variable amounts of data exchange, there is a need for stable,

secure and reliable network environment. Thus, the second level of the model classifies users: service providers and end users; which have specific interests versus the defined objectives related to the infrastructure, platform, and application (level 3). At the fourth level, infrastructure provider objectives can be divided into those related to income maximization and those related to expense minimization. Income objectives are classified as quality of service (QoS) based and security based.

Expense objectives are divided into: resource usage and efficiency of resource usage. Accordingly, we have defined and provided a mathematical modeling of a set of featured objectives to fulfill the IoT business sustainability principles. We will focus to QoS and security, while other goals, due to the available paper length will be explained in brief. Quality of service (QoS) can be estimated providing that a set of design variables listed in Table I:

TABLE I.
QoS DESIGN VARIABLES

Variable	Identifier
Number of servers	N_S
Server _i	S_i
Number of VMs	N_{VM}
Virtual machine _j	VM_j
No. of ph. CPUs on server S_i	S_i^{CPU}
No. of virtual CPU cores on VM _j	VM_j^{CPU}
RAM size on server S_i [GB]	S_i^{RAM}
RAM size on VM_j	VM_j^{RAM}
Ph. storage size on ph. server S_i [TB]	S_i^{str}
VM_j image size [TB]	VM_j^{im}
Server network traffic [GB/s]	S_i^{bw}
VM_j network traffic bandwidth	VM_j^{bw}
Hypervisor type and parameters	$Hypervisor_i^{type}$
CPU scheduling type and parameters related to hypervisor	CPU_i^{sch}
No. and type of magnetic HDs	HDD^{num}
Hard Disk _i	HDD_i
Hard Disk _i size [TB]	HDD_i^{size}
Type and number of SSDs	SDD^{num}
SSD Disk _i	SDD_i
SSD Disk _i size [TB]	SDD_i^{size}
RAID type and parameters	$RAID_i^{type}$
Filesystem type and parameters	FS_i^{type}
VMs distribution	$S_i \leftrightarrow VM_j$
VMs migration	$VM_j(S_i \rightarrow)$
VMs images migration	$VM_j^{im}(S_i \rightarrow)$
System of the VMs images replicas	$VM_j^{im_rep}(S_i \rightarrow)$

QoS is assessed by a number of appropriate relations and is defined by goals required to be accomplish when delivering the IoT-Cloud to the user:

$$QoS(S_i, VM_j) = f(QoS_DesignVariables) \quad (1)$$

where $QoS(S_i, VM_j)$ is a multivariable function for evaluation of the performances. In general it also targets the estimation of the fault tolerance, available resource, load balancing, and scalability, which depend on a set of features that are grouped as quantifiers. First set represents quantifiers of physical resources:

$$I_{gf} = f(N_S, S_i, S_i^{CPU}, S_i^{RAM}, S_i^{st}, S_i^{str}, S_i^{bw}, HDD_{param}, SDD_{param}, RAID_i^{type}, FS_i^{type}) \quad (2)$$

where HDD_{param} and SDD_{param} depend on the number, features and size of HDD/SDD disks. The next group of quantifiers describes virtual resources:

$$II_{gf} = f(N_{VM}, VM_j, VM_j^{CPU}, VM_j^{RAM}, VM_j^{im}, VM_j^{bw}, HP^{type}, CPU_{HP}^{sch}) \quad (3)$$

Third set of quantifiers defines activities {migrations, distributions, replications} in virtual environment:

$$III_{gf} = f(S_i \leftrightarrow VM_j, VM_j(S_i \rightarrow), VM_j^{im}(S_i \rightarrow), VM_j^{im_rep}(S_i \rightarrow)) \quad (4)$$

QoS maximization as Goal O_1 is further defined based on the relations (1)-(4):

$$O_1 = \max QoS(S_i, VM_j) \quad (5)$$

QoS performances rely on a large number of variables:

$$QoS(performances) = f(I_{gf}, II_{gf}, S_i \leftrightarrow VM_j, VM_j(S_i \rightarrow S_k)) \quad (6)$$

while reliability and availability are highly dependable on VM manipulation operations: migration, images migration and system of image replicas (7, 8):

$$QoS(reliability, availability) = f(RAID_i^{type}, VM_{manip}) \quad (7)$$

$$VM_{manip} = f(VM_j(S_i \rightarrow S_k), VM_j^{im}(S_i \rightarrow S_k), VM_j^{im_rep}(S_i \rightarrow S_k)) \quad (8)$$

Another important aspect to consider in IoT is security plan. The goals related to security focus to bringing high levels of sensitivity, specificity and accuracy of the security systems. Yet, the main obstacle for gaining the best possible security performances, are QoS and energy efficiency objectives, as these are in the divergence with the security limitations.

Intrusion Detection/Prevention Systems (IDS/IPS) represent the basic support for system security provisioning. IDS/IPS provide detection, classification and further reaction to the detected malicious events in the supervised system environment. As there is no ideal algorithm that will provide absolute detection accuracy, some normal activity is classified as malicious, gaining tag of being false positive (FP).

Alternatively, some malicious traffic can skip the IDS scanning capabilities and treated as normal traffic (false negative (FN)). True positives (TP) and true negatives (TN) stand for real normal events detected as such, and

malicious traffic that is correctly detected, respectively. IDS/IPS sensitivity and specificity are defined base in the collected TP and TN events rates.

Further we define Goal O_2 - the sensitivity maximization, and Goal O_3 - the specificity maximization:

$$sensitivity = TP_{rate_i} = \frac{TP_i}{TP_i + FN_i}, \quad O_2 = \max TP_{rate}(TP_{rate_i}) \quad (9)$$

$$specificity = TN_{rate_i} = \frac{TN_i}{TN_i + FP_i}, \quad O_3 = \max TN_{rate}(TN_{rate_i}) \quad (10)$$

The resources usage are measured through energy use for the operations of IoT devices and adequate CC infrastructure, the cost of the used administrative time, and the use of non-IT components and time. The energy consumption is the most important component, as it depends on the CPU energy usage, energy spent on network components, and energy for storage operations. Resource efficiency is decomposed to efficiency of: CPU, RAM memory use, storage space use, and network traffic. We will not repeat the discussion on these design variables due to their high overlapping with QoS objectives variables. Resource use efficiency is calculated according to:

$$\varphi_1(S_i, VM_j) = \frac{\sum_{j=1}^{N_{VM}} VM_j^{CPU} + \sum_{j=1}^{N_{VM}} VM_j^{RAM} + \sum_{j=1}^{N_{VM}} VM_j^{im} + \sum_{j=1}^{N_{VM}} VM_j^{bw}}{\sum_{i=1}^{N_S} S_i^{CPU} + \sum_{i=1}^{N_S} S_i^{RAM} + \sum_{i=1}^{N_S} S_i^{str} + \sum_{i=1}^{N_S} S_i^{bw}} \quad (11)$$

Table II provides details related to the set of selected goals.

We define Goal O_4 as reaching the maximization of φ_1 , which depends on optimal deployment and migration of virtual machines. Goal O_5 is defined as accessing the minimization of the number of VM migrations. The number of migrations of virtual machines is calculated according to:

$$\varphi_2(VM) = \sum_{j=1}^{N_{VM}} VM_j(S_i \rightarrow S_k) \quad (12)$$

Goal O_6 searches for the minimization of energy consumption.

The listed variables depend on the values obtained from calculating statistical power consumption for each CPU and for all CPUs.

TABLE II.
CLOUD COMPUTING AND INTERNET OF THINGS RELATIONSHIP.

Goal O_1	QoS maximization	$O_1 = \max QoS(S_i, VM_j) = \max f(QoS_DesignVariables)$ $QoS(performance) = f(I_{gr}, \Pi_{gr}, S_i \leftrightarrow VM_j, VM_j(S_i \rightarrow S_k))$
Goal O_2	Sensitivity maximization	$O_2 = \max TP_{rate}(TP_{rate_i})$
Goal O_3	Specificity maximization	$O_3 = \max TN_{rate}(TN_{rate_i})$
Goal O_4	Resource use efficiency maximization	$O_4 = \max \varphi_1(S_i, VM_j) \quad \varphi_1(S_i, VM_j) = \frac{\sum_{j=1}^{N_{VM}} VM_j^{CPU} + \sum_{j=1}^{N_{VM}} VM_j^{RAM} + \sum_{j=1}^{N_{VM}} VM_j^{im} + \sum_{j=1}^{N_{VM}} VM_j^{bw}}{\sum_{i=1}^{N_S} S_i^{CPU} + \sum_{i=1}^{N_S} S_i^{RAM} + \sum_{i=1}^{N_S} S_i^{str} + \sum_{i=1}^{N_S} S_i^{bw}}$
Goal O_5	Minimization of the number of used virtual machines	$O_5 = \min \varphi_2(VM), \quad \varphi_2(VM) = \sum_{j=1}^{N_{VM}} VM_j(S_i \rightarrow S_k)$
Goal O_6	Minimization of energy consumption	$O_6 = \min P_{CPU}, P_{CPU} = \sum_{i=0}^{N_{CPU}-1} \sum_{j=0}^{N_{CPU}-1} \alpha_{i-j}^{CPU} * P_j^{CPU} \quad \alpha_{i-j}^{CPU} = f(Hypervisors_{type}, CPU_{sch}, S_i \leftrightarrow VM_j, VM_j(S_i \rightarrow))$
Goal O_7	Power consumption minimization	$O_7 = \min P_{str}, \quad P_{str} = P_{HDD} + P_{SSD}$
Goal O_8	Energy efficiency maximization	$O_8 = \max EE, \quad EE = \frac{QoS}{P}$
Goal O_9	Maximization of the storage energy efficiency	$O_9 = \max EE(str), \quad EE(str) = \frac{QoS(str)}{P_{str}}$
Goal O_{10}	Maximization of the networking energy efficiency	$O_{10} = \max EE(networking), \quad EE(networking) = \frac{QoS(networking)}{P_{networking}}$

The statistical power consumption depends on the probability of P_j state of the CPU_i :

$$P_{CPU} = \sum_{i=0}^{N_{CPU}-1} \sum_{j=0}^{N_{CPU}-1} \alpha_{i-j}^{CPU} * P_j^{CPU} \quad (13)$$

where the probability of a specific state for CPU is:

$$\alpha_{i-j}^{CPU} = f(Hypervisors_{type}, CPU_{sch}, S_i \leftrightarrow VM_j, VM_j(S_i \rightarrow)) \quad (14)$$

In the similar way, we can estimate the storage power consumption goal which depends on the used disk technology, and relies on the statistical power consumption for individual P_{HDD_i} and P_{SSD_i} , and statistical power consumption of all disks, P_{HDD} and P_{SSD} . Table II provides information on the calculations on goals O_7 (P_{str} minimization), O_8 (energy Efficiency (EE)) CPU/Storage maximization), O_9 (maximization of

EE networking performances) and O_{10} (maximization of networking energy efficiency) which are defined according to values:

$$P_{HDD/SSD} = \frac{HDD/SSD^{num-1}}{\sum_i P_{HDD_i/SSD_i}} = \frac{HDD/SSD^{num-1} N_{HDD/SSD}^{-st-1}}{\sum_{j=0}^{HDD/SSD} \alpha_{i-j}^{HDD/SSD} * P_j^{HDD/SSD}} \quad (15)$$

where α_{i-j}^{DT} can be calculated according to the relation 16. DT stands for "disk type":

$$\alpha_{i-j}^{DT} = f(DT_{params}, N_{VM_S}, FS_i^{dpe}, RAID_i^{dpe}, III_{df}) \quad (16)$$

The proposed MO analysis is multiple step process. Radar diagram given in Figure 4 provides one possible appropriate way of visualizing and comparison of the selected goals and their respective values obtained by the arbitrary parameter estimation for the IoT network/system under the analysis. It provides an example of two different estimations (A and B) of the selected objectives, and indicates objectives that should be enhanced or paid additional attention to.

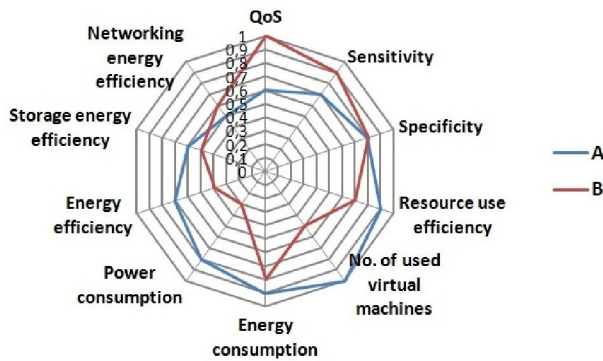


Figure 4. "IoT-Cloud" chart for multiple quantitative variables comparison

V. CONCLUSION

This paper provides a sustainability assessment perspective of the Internet of Things paradigm, taking into consideration the relation to the cloud computing environment and demands for IoT business growth in such environment. IoT is believed to be one of the most important nowadays Mega Trends. The integration of the IoT to the proposed Multi Objective Cloud Computing Sustainability Assessment model is presented by means of a set of defined objectives that should be fulfilled in order to provide proper, secure, and QoS enabled environment.

Further work will be focused to stronger support for integration of Open/Private/Public data and, depending on the volume and ontological specification, the integration and more efficient use of Big/Smart Data. The appearance of diverse worldwide green initiatives that are raised as a consequence of intensified IoT involvement to all human life aspects is bringing additional bustle in IoT application possibilities and development directions.

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