THE IMPACT OF INTERNET OF THINGS IN CLOUD COMPUTING: PRESENT AND PERSPECTIVES

FURDU IULIAN[14]

[1] *"Vasile Alecsandri" University of Bacău, Calea Mărăşeşti 156,Bacău, 600115, Romania*

***Abstract*:** This paper aims to presents how the potential of Internet of Things will change the future of Cloud. The next generation of cloud technologies will be strongly influenced when standardization and communication platforms will become an Internet of Things reality. An example is provided to describe how an Internet of Things device could became operational on the web. Actual and emerging techniques for Internet of Things implementation are discussed and related open issues concerning to the relation between Internet of Things applications and Cloud are investigated and potential solutions are explored.

Keywords: Cloud, Internet of Things, Smart environments, Ubiquitous sensing.

1. INTRODUCTION

The paper addresses two convergent domains that are nowadays very popular paradigms: Cloud Computing an Internet of Things. Internet of Things (IoT) can be seen as a grid of all the things that we connect to Internet and, through all the huge amount of data that we share, we need the possibility to perform higher computations that can help us in decision making process. Cloud computing extends the Web with computational facilities because represents a way to take advantage of the computing resources and data shared across the Internet. A cloud computing environment favors sharing resources for a common use or purpose. The origins of cloud computing lie in networked computing, distributed computing, and parallel computing [1] and cloud computing could benefits of the advantage of a wide collaboration between computer networks to perform large tasks. From a similar perspective, in [2] authors consider that "grid computing is all about virtualization that enables businesses to take advantage of a variety of IT resources in order to be more responsive to demands of the business and increase availability of applications, while reducing both infrastructure and management costs". IoT refers to a world where real objects are linked to the virtual world. These heterogeneously connected devices have computation and communication capabilities. IoT is a paradigm that also combines aspects and technologies from different approaches like ubiquitous computing, Internet Protocol, sensing and communication technologies [3]. In other words, the surrounding objects become smart objects that are able to collect information about the environment they interact with and also to connect one to each other through the Internet. This will lead to a huge amount of data that raises one question: how to compute these data in order to bring benefits to the society, economy, industry and any individual in general?

2. CLOUD COMPUTING AND IOT

Cloud represents a platform for coordinated resource sharing (high performance equipment, computers, software, and data) and problem solving on a global scale. The scope of IoT is to embed real world information into

[4] Corresponding author e-mail: ifurdu@ub.ro

networks, services and applications through dedicated technologies like wireless sensor and actuator networks, ubiquitous device assemblies and coding systems [4]. The coding systems could be for example 2D bar coding system (Quick Read (QR) Code) or Radio Frequency Identification (RFID) tags that are attached to an object. These codes contain numerous type of information that permits objects to have a detailed description, unlike a standard bar code identification that contains only few numeric identification. The advantages of QR codes are that majority of smart-phones can read these codes and than display a web site address, as the resource address of the object, which sometimes is hard to type or to find.
In the next chapter is presented a simple example on how to make grid computations within cloud. The example is implemented in MPI-base grid applications because MPI (Message Passing Interface) is a widely used parallel programming model and is the effective standard for high performance scientific computing [5].

3. COMPUTING IOT DATA

Firstly, we need to establish a way to represent objects and the connections between them. An object is identified using a RFID tag, but also a specific vocabulary to include meta-data about things on the Internet is needed [13].
A vocabulary to describe knowledge about things implies using an ontology. The ontology is a formal, explicit specification of a shared conceptualization [6]. Ontologies provide also description of the structure of concepts and relationships between concepts, declarations of classes and subclasses, types, and cardinality for the properties of concepts. Thus, they provide therefore adequate support to achieve rule-based reasoning and inference [7].
In the following example we will describe few objects representing some products from a business company. Suppose these products are things connected to Internet, having a RFID associated. When a customer uses his smart-phone to detect the RFID tag, he can obtain almost everything that he needs to know about that product.
Because IoT means “anytime, any place connectivity for anyone, to a situation where we will now have connectivity for anything” [8], the example aim is to present the idea of virtual connecting of all the products that a company have for sale. An ontology will be created for these products to describe concepts (objects or things) where each concept has some properties, like price, RFID tag, short name, etc. A simple, but efficient computation that can be make based on the description of products is a regular balance sheet to find the total assets of that company. If we imagine that the company has multiple stores in different cities and different categories of products, and millions of products in total, it is obvious that a parallel computation with n processors to calculate the total values per group of products, per store, can be a the suitable and efficient solution. The example is adapted after a previous example presented in [9].
Further, the ontology is described. First, we have a series of namespaces declarations coresponding to semantic web standards to create the ontology. We present here only three classes/concepts: Assets, InvestmentProperty and Constructions which are part of a bigger class, Expenses.

```
// Classes or concepts
<owl:Class rdf:about="http://simulator/OntologyBalanceSheet.owl#Assets">
</owl:Class>
```

These clasese represent a group of products.

```
<owl:Classrdf:about="http://simulator/OntologyBalanceSheet.owl#Laptop”>
<rdfs:subClassOfrdf:resource="http://simulator/OntologyBalanceSheet.owl#Assets"/></
owl:Class>
<owl:Classrdf:about=”http://simulator/OntologyBalanceSheet.owl#Printer”>
<rdfs:subClassOfrdf:resource="http://simulator/OntologyBalanceSheet.owl#Assets"/></
owl:Class>
```

The concept properties are declared below. The first property is *hasValue* which means the value in money corresponding for that product. The other two properties are *hasCurrency* to describe the type of money that we use and the third property is *hasCode* representing the RFID code.

```
// Data properties
<owl:DatatypeProperty                                    rdf:about="http://simulator/
OntologyBalanceSheet.owl#hasValue">
  <rdfs:range rdf:resource="&xsd;longint"/>
  <rdfs:domain        rdf:resource="http://simulator/OntologyBalanceSheet.owl#Assets
"></owl:DatatypeProperty>

<owl:DatatypeProperty
```

```
rdf:about="http://simulator/ OntologyBalanceSheet.owl#hasCurrency">
  <rdfs:range rdf:resource="&xsd;string"/>
  <rdfs:domain        rdf:resource="http://simulator/OntologyBalanceSheet.owl#Assets
"></owl:DatatypeProperty>

<owl:DatatypeProperty
rdf:about="http://simulator/OntologyBalanceSheet.owl#hasCode">
  <rdfs:range rdf:resource="&xsd;"/>
  <rdfs:domain        rdf:resource="http://simulator/OntologyBalanceSheet.owl#Assets
"></owl:DatatypeProperty>
```

Further, concrete products that the company have are added (defined as namedindividuals in ontology):

```
<owl:NamedIndividual rdf:about="Laptop#Asus_model5">
<hasValue rdf:datatype="&xsd;longint">2000</hasValue>
<hasCurrency rdf:datatype="&xsd;string">Euro</hasCurrency>
<hasCode                  rdf:about="http://www.generatorqr.ro/codes/qr/2014-09-
18/1411087968.png"></hasCode>
```

After the ontology is created we can proceed with our computations using MPI standard. We want to calculate for each concept/class or category of products the total assets. Each separate category calculation is done by a different process. In the end, all the slave processes will send to the master process the results, the master process will compute all the received results and return the total value. For each process that calculate the value per category, we first extract all the values for all the products in each category in separate vectors using the SPARQL (SPARQL Protocol and RDF Query Language) for Semantic Web standards. Once we have the vectors with products values we proceed with the MPI computations, while the information sent to each process represents the information from the ontology file:

```
for(i=1;i<nrproc;i++) mesageout[i]=Ontology_file(file);
```

If it is the master process, it will send messages to each slave, otherwise a slave process receives the message from the master. After all the messages where received the sum of the assets per categories is calculated, and the result is kept in the *rezult* variable: `MPI_Reduce(&mesagein[i],&rezult,nrproc-1,MPI_INT,MPI_SUM,0,MPI_COMM_WORLD);`
This is just a simple example on how can be made computations for IoT data in grid computing, using virtual machines within a cloud environment.

4. THE RELATION BETWEEN IOT AND CLOUD COMPUTING: PRESENT AND PERSPECTIVES

Since the physical devices that involve sensing and actuation are to form an important part of the future internet, the IoT will became the key point of the impact between sensing environments and Clouds. Thus, things that are communicant become gates to interact with our environment or to each other. From this perspective cars, smartphones, domestic devices etc. can be identified, allocated and could contribute in sensing and analyzing aspects of people's lives that were previously unknown or invisible [10]. New levels of infrastructure abstractization will be obtained using semantics: efficient semantic annotation of sensor data is a research field where much effort is done to improve the reactivity and the level of scalability for sensor networks. New dedicated operating systems like Contiki and TinyOS are designed to manage the integration of such devices within the internet. IoT must have a high level of interoperability and a good degree of flexibility due to heterogenous sensing networks. Nowadays, research is conducted to discover and to enhance the role of IoT objects/devices in healthcare, smart cities, risk management/emergency services, transportation (cloud service for intelligent parking, and vehicular data mining cloud service [11]), efficient logistics management, and communication. Cloud computing can provide the infrastructure for utility computing which integrates scalability and autonomy to provide ubiquitous access, monitoring and storage devices, analytics tools, visualization platforms, dynamic resource discovery and composability required for the next generation IoT applications. The actual demands for IoT includes i) new bindings to handle mappings between physical environments related to IoT and virtual, Cloud environments [12]; ii) low-cost sensors which result in a high level of noise and weak communication equipments should be compensated by analyzing with sophisticated algorithms cross-correlation of sensed data from several sensors [10] iii) interoperability issues when scaling across multiple Clouds. A solution can be Aneka, an application development Platform-as-a-Service (PaaS, .NET based), which manges the storage and can compute resources of both public and private clouds; iv) WSN issues concerning security, architecture and protocols, efficiency in using energy: standardization of protocols and frequency bands is the key point in finding a solution [12].

5. CONCLUSIONS

The paper addresses two very interesting domains and raises a question on how we can manage different computations on IoT network data.

The combination of these two paradigms was not sufficient discussed and analyzed in the literature review. We consider that this topic necessitates a much more interest from the researchers part because of the "becoming a reality" start of the IoT. The "big" dream about creating The Grid, is also evolving, even if slowly, nowadays several small grids already have been created. Considering the amount of data that will be created in the virtual space in the near future it is clear that we need higher-performance cloud technologies.

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