IoT and Cloud Convergence: Opportunities and Challenges

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***Abstract*— The success of the IoT world requires service provision attributed with ubiquity, reliability, high-performance, efficiency, and scalability. In order to accomplish this attribution, future business and research vision is to merge the Cloud Computing and IoT concepts, i.e., enable an "Everything as a Service" model: specifically, a Cloud ecosystem, encompassing novel functionality and cognitive-IoT capabilities, will be provided. Hence the paper will describe an innovative IoT centric Cloud smart infrastructure addressing individual IoT and Cloud Computing challenges.**

Keywords—Internet of Things; Cloud Computing; Convergence;

I. INTRODUCTION

The Cloud Computing concept has greatly matured over the last few years. The concept means that anything that can be hosted on the Internet, i.e., resources/services/data is available for use, when needed, for the composition and provision of more sophisticated services. Key cloud characteristics are: on-demand service provision, ubiquitous access, resource pooling, as well as elasticity.

In the meantime the "Internet of Things" (IoT) vision has evolved and is coming to reality. The IoT involves several billions of diverse devices inter-connected by 2020 [1] vast amounts of quickly-emerging/versatile data (i.e., "big data"), and numerous services. Connected devices can be sensors, actuators, smart phones, computers, buildings and home/work appliances, cars and road infrastructure elements, and any other device or object that can be connected, monitored or actuated. Devices are connected to the Internet, as well as with each other, via heterogeneous access networks. Services aim at leading to a smart, sustainable and inclusive society and economy. In the light of the issues discussed, the success of the IoT services can only be achieved if they are attributed with ubiquitous accessibility (i.e., more business opportunities), reliability (e.g., for handling context/policy changes and accomplishing trust from the parts of the users), high-performance (e.g., due to the associated "big data"), efficiency (for improving the position of all stakeholders, e.g., providers and users), and scalability (e.g., as various volumes of users, resources and data may be involved in service provision).

The Cloud features mentioned in the first paragraph are essential today for the IoT world. For instance, resource pooling enhances the reliability and efficiency of service provision, the on-demand and elasticity features are fundamental for efficient and scalable service provision (resource provision where needed, for the amount of time needed), etc. All these facts make a more than compelling case for the merging of the Cloud and IoT paradigms.

II. IOT AND CLOUD CHALLENGES AND HAPPY MARRIAGE

IoT is the vision of future connected world. In order to realize this vision targeting future market potential several requirements have to be taken into account, for example i) *Ubiquitous accessibility* and connectivity, facilitation of maximum accessibility as well as connectivity of the diverse heterogeneous objects/services and various volumes of users including mobility through commonly agreed APIs and standards ii) *Dynamic management/orchestration* of users, billions of devices as well as massive amount of data produced by those connected devices iii) *Maximum resources utilization,* enabling of sharing of IoT resources (objects, applications, platforms) iv) *Personalization of users and services,* providing services based on users preference and requirements including real-world context. All the above functionalities have to be i) reliability (e.g., for handing context/policy changes and accomplishing trust from the parts of the users) and ii) *Scalability* (e.g., as various volumes of users, resources and data may be involved in service provision)

A. What Cloud can offer?

Cloud computing relies on sharing of resources, which is key requirements for IoT platform. The Cloud Computing is not only sharing the resources but also maximizing the resources. It is also location independent, the users access the cloud services from any location and with any devices through the internet connection. When we talk about the IoT platform then it should also be access from anywhere, any time. The virtualization of physical devices is another imporrant characteristics, virtualization allow users to easily share the devices. Due to virtual world nature, it is also more homogeneous. Multitenancy feature of cloud computing enables sharing of resources to multiple users over spatial and time distribution. In addition, Cloud offer elasticity and scalable of resources and application, the service and resources are easily accessible and available. Hence the convergence of Cloud and IoT can provide huge opportunities for both technologies.

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B. *Convergence of IoT and Cloud*

Two main approach's for this convergence are foreseen i) Cloud-based IoT which is to bring IoT functionalities into Cloud ii) IoT-Centric Cloud which is to bring Cloud functionalities into IoT. This convergence has substantial impacts on both sides. For IoT to provide cloud computing functionalities, to support on realization of IoT vision. For Cloud, IoT to provide huge opportunities for cloud services. In the following session we have described the IoT-Centric Cloud approach.

III. IoT-Centric Cloud

IoT-Centric Cloud is a paradigm that extends Cloud computing and services to the edge of the network, close to objects. The idea is to distribute data to move it closer to the end-users to eliminate latency, reduces high traffic, numerous hop, and support mobile computing and data streaming. In this paradigm, the data is processed and storage close to users/near to sources. This creates dense geographical distribution and supporting end-users security. It is useful when service is provisioned from the data coming from same location. In this approach, rata process and service execute locally (distributed cloud processing, sub-work flow, data aggregation locally). Unlike traditional data centers, IoT devices are geographically distributed over heterogeneous platforms, spanning multiple management domains. Thanks to its wide geographical distribution the IoT-Centric Cloud paradigm is well positioned for real time big data and real time analytics. IoT-Centric Cloud supports densely distributed data collection points, hence adding a fourth axis to the often-mentioned Big Data dimensions (volume, variety, and velocity) [2].

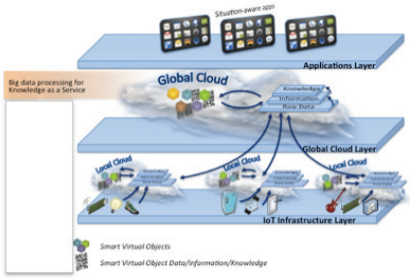

Fig 1: IoT-Centric Cloud ecosystem

The IoT-Centric Cloud ecosystem [3] consists of *Local Clouds* and a *Global Cloud*. More specifically:

- A Local Cloud is created on-demand, it comprises the sufficient/appropriate computing/storage/ networking capabilities, and provides requested services to users in a certain geographical area and time period as well as offers additional processing and storage capability to services.
- The Global Cloud is seen in the "traditional" sense, as a construct with on-demand/elastic (illusion of infinite) processing power and storage capability. It is a "backbone infrastructure", which increases the business opportunities for service providers, the ubiquity/reliability/performance/efficiency/ scalability of service provision (more opportunities for offering services, more options on which to base service features in case of context changes, more resources for contributing to the decisions, elastic provision of resources on demand, etc.).

Local Clouds can involve an arbitrary large number of nodes (sensors, actuators, smartphones, etc.). The aggregation of resources comprises sufficient processing power and storage space. Networking can rely on heterogeneous technologies (wireless plays a prominent role). The goal is to serve users of a certain area. In this respect, a Local Cloud is the virtualised processing, storage and networking environment, which comprises IoT devices in the vicinity of the users; users will exploit the various services composed of the Local Cloud's devices' capabilities.

IV. New Challenges due to IoT and Cloud Combinaton

Although IoT and Cloud combination can overcome several individual IoT and Cloud challenges, however due to convergence of these two technologies additional challenges are foreseen. Most of the IoT data are un-structure and semi-structure those are coming from distributed sources, in addition massive amount of data coming from IoT sources. IoT-Cloud has to provide real-time data processing and service provisioning techniques considering such Big Data. Another issues are to provide more dynamic resources management and orchestration techniques, dynamically offloading from clients/hosts to cloud (both at design and run time including mobile users and applications). Providing more distributed processing and storage of the massive data as well as cloud functionalities. In addition to above other issues are an important i) *Virtualization of IoT devices*- Access to advanced resources/specialized hardware, including GPUs, sensors, etc. ii) *Portability* of the services- Migration of servers to follow mobile users iii) *Reliable and real-time communication* from objects to applications and maximum accessibility and connectivity iv) *Interoperability* between cloud/IoT services and infrastructure vi) *Accountability* Services and data hosted and executed across borders vii) Enabling reliable and real-time *communication* from objects to applications and vice-versa;

V. CONCLUSION

In this paper the convergence of IoT and Cloud techniques and their opportunities and challenges are described. The reason for such IoT and Cloud combination as well as one approach IoT-Centric Cloud is described. The paper also outlined the up coming open challenges for such Cloud and IoT convergence.

References

[1] Internet of Things propels the Networked Society", Ericsson Labs Blog by Ericsson Research, available at https://labs.ericsson.com/developer-community/blog/internet-of-things-propels-the-networked-society

[2] www.cisco.com

[3] "IoT Centric Cloud: A catalyst for innovation in Europe", Netowrking Session, ICT event 2013, 6-8th November, 2013