

Convergence of Internet of Things with Cloud: A Survey

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Abstract - Internet of Things (IoT) is becoming the next emerging technology after cloud computing. Cloud Computing provides on-demand, scalable network access, resource sharing on “pay-per-use” basis via Internet. It provides a new way of storing and managing the data. Instead of storing and processing the data on local servers, it is processed and stored on remote servers. On the other hand, IoT is the next Internet related revolution. It allows Internet to be used for connecting not only human beings but also physical objects for making day-to-day life easier. Machine to Machine (M2M) communication is the core vision of IoT. This paper gives an overview of these two emergent technologies having specific characteristics, benefits and limitations. It also shows how some of the features of these two can be complemented to get maximum outcome. We have also discussed the numerous benefits that derive the convergence of IoT with Cloud. Hereby, the cloud and IoT have become two very closely associated future internet technologies with one providing the other a platform for success.

Keywords: *Internet of Things, Cloud Computing, Convergence, Integration.*

I. INTRODUCTION

In modern era, the use of Information and Communication Technology has spanned across each and every aspect of lifestyle. This is the current scenario in the field of ICT with two emerging technologies - Cloud Computing and the Internet of Things (IoT). These two paradigms have many common as well as distinct characteristics. Cloud Computing defines a new way of service delivery as it has changed the way we deliver and use Software and Infrastructures. Cloud Computing provides on-demand, scalable, “pay-per-use” services as and when required (Jadeja & Modi, 2012). On the other hand, IoT allows us to connect with Anyone, Anywhere and Anytime using any type of service. That means it provides communication between any types of devices with minimum human intervention. The IoT normally includes a number of objects with limited storage and computing capacity (Babu, et al., 2015). Whereas, Cloud provides large, virtually never ending storage and processing capability. It could well be said that Cloud computing and the IoT will be the future of the Internet and next-generation technologies. Hence the two should go hand-in-hand for the benefit of the ICT as well as every aspect of lifecycle.

This paper provides an overview of the convergence of IoT into Cloud Computing. It focuses on benefits resulting from the convergence process. The remainder of the paper is organized as follows: Section II provides the basic concepts

of Cloud computing and Internet of Things. Section III discusses the role of cloud in success of IoT and Section IV describes the cloud computing framework for IoT.

II. BACKGROUND AND BASIC CONCEPTS

A. Cloud Computing

Cloud computing is a type of computing that provides a common platform for sharing computing resources rather than having local servers or personal devices to handle applications. It's called Cloud Computing because the information being accessed is found in "the cloud" and does not require a user to be in a specific place to gain access to it. (Buyya, et al, 2009). It allows users to work remotely, store files and applications on remote servers, and then access all the data via the internet. It is the way of storing and accessing the data and programs over the Internet (Ambrust, et al, 2010). According to NIST, Cloud computing is "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell & Glance).

As shown in figure 1 Cloud Computing has:

- Five Essential Characteristics : On-demand self-service, Broad network access, Resource pooling, elasticity, Measured Service .

- Three Service Models : Cloud Software as a Service (SaaS), Cloud Platform as a Service (PaaS), Cloud Infrastructure as a Service (IaaS) .
- Four Deployment Models: Private Cloud, Community cloud, Public cloud, Hybrid cloud.

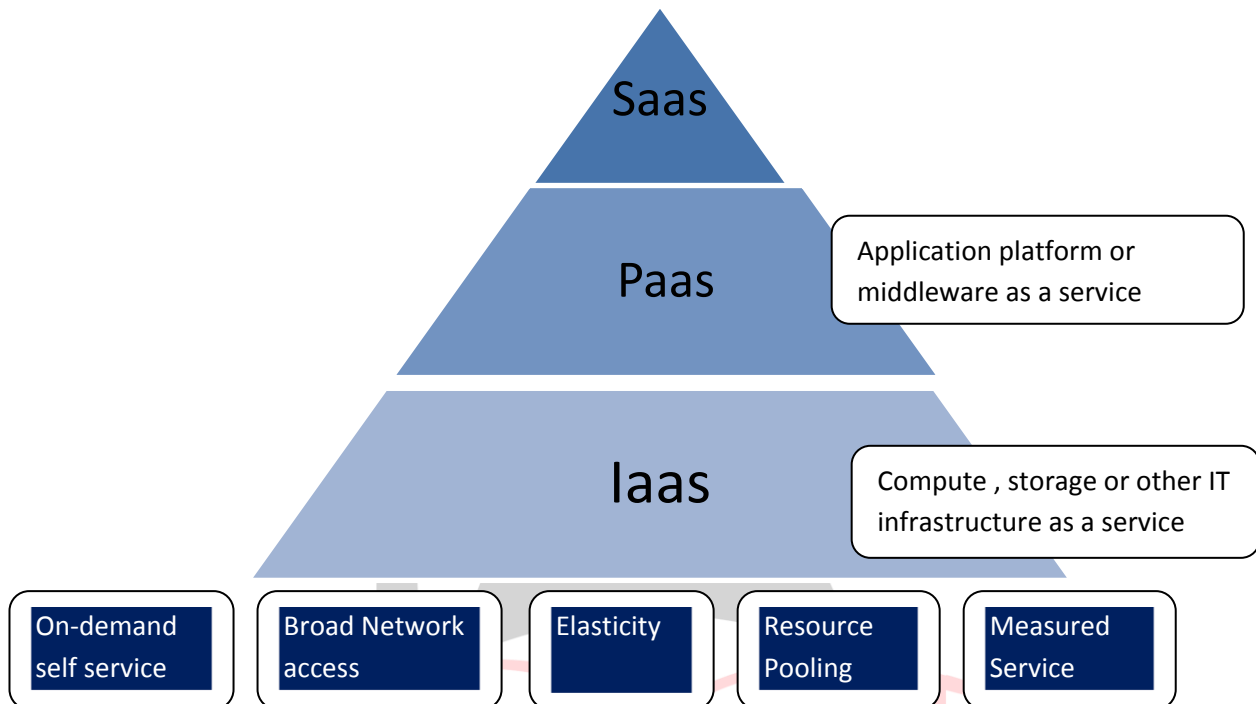


Figure 1 : Cloud Service Models

B. Internet of Things:

The Internet of Things is a new paradigm growing rapidly these days in the era of wireless communication (Miorandi, et al, 2012). Till date most of the communication involves human beings using smart phones or computer system but in future most of the devices (Things) will actively participate in this communication, machines will talk to each other without human intervention and it will be machine to machine (M2M) communication using Internet. These devices include not only daily usable electronic devices, but also things like food, clothing, materials etc.

The concept of the IoT was first introduced by Kevin Ashton in 1999 (Ashton, 2009) defining IoT as “*The Internet of Things has the potential to change the world, just as the Internet did. Maybe even more so*” (Joshi & Kim, 2013). According to the (ITU, 2012), the IoT is “a global infrastructure for the Information Society, enabling advanced Services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies”.

IoT is a next step in the evolution of the Internet rather than a new revolution in computing world. It includes various technologies (e.g. sensor hardware/firmware, cloud, data

storing, modeling, reasoning, processing and communication technologies) together to fulfill its vision. The existing technologies can be applied in different ways according to the characteristics and needs of the IoT (Perera et al., 2014).

III. MOTIVATION

Convergence of IoT with Cloud

IoT with Cloud Computing increases the efficiency of everyday tasks and both have a complementary relationship.(Botta, et al, 2014). On one hand, IoT generates lots of data while on the other hand, cloud computing provides storage and manages this data.(Atlam,et al., 2017) Internet-of-Things can benefit from the characteristics of Cloud like scalability, performance and pay-as-you-go nature. Indeed, as IoT applications produce large volumes of data and comprise multiple computational components (e.g., data processing and analytics algorithms), their integration with cloud computing infrastructures could provide them with opportunities for cost-effective on-demand scaling. (internet-of-things-iot-cloud, 2017) .

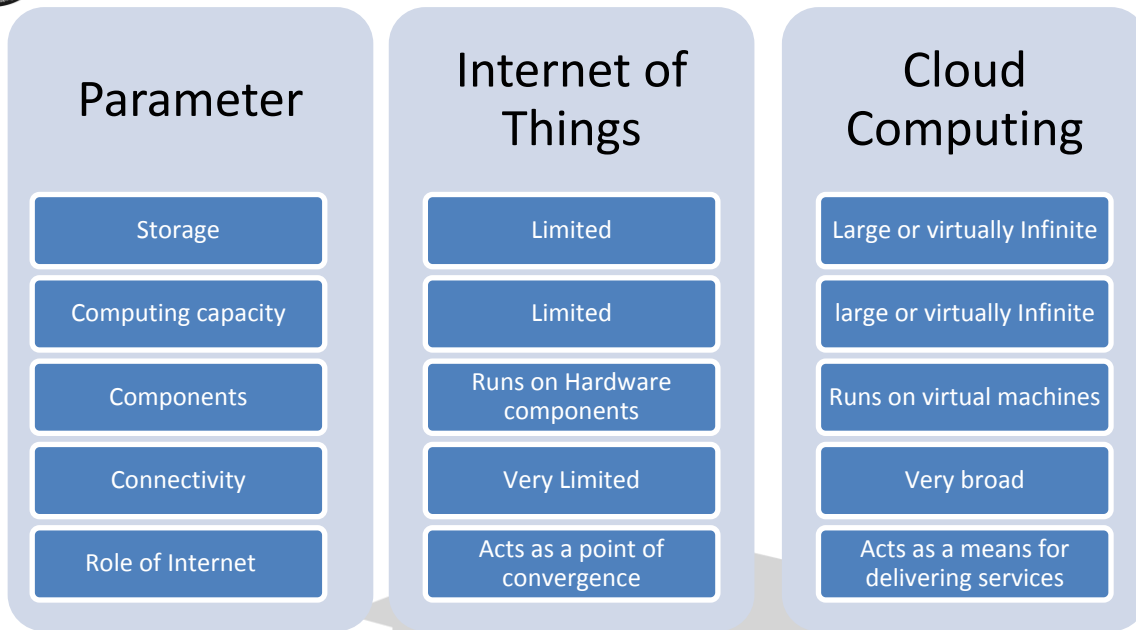


Figure 2: Cloud-IoT Convergence

Role of Cloud in Success of IoT:

Storage: IoT contains million of sensors that generate large number of data, which is to be collected and aggregated to a sink node for further analysis and make decisions accordingly. The problem arises with the limited storage capabilities of devices that can't store large amount of data. Cloud computing is the potential solution for storing this data by using Infrastructure-as-a-service model of Cloud.

Computing Power: IoT devices normally have very limited battery life and processing power, hence they can't handle the computation required for further decision making. Therefore a need arises to offload this computation to some other powerful computer. Cloud provides them with on-demand processing power which is virtually infinite.

Connectivity: In an IoT, the sensors not only talk to the users, they also interact with each other. Cloud applications along with the IoT gateway ensure that different sensors

and actuators are able to talk to each other without any incompatibility.

Big Data Analytics and Monitoring: With a large number of 'things' now being connected, there would be a need for real time analysis and monitoring of the Big Data. This Big data is managed using the cloud's virtually never ending resources.

Hereby, both cloud and IoT share strong relationship to form cloud-based IoT applications to make the most out of their combination which has led to the success of IoT.

Cloud Computing Framework for IoT

Figure 3 shows the Cloud Computing Framework for IoT that explains how the Cloud Computing has become an integral part of IoT architecture. According to (Gubbi, et al., 2013),

Cloud Computing acts as intermediate layer between Sensor Layer known as 'Network of Things' and application layer, providing storage, processing power, Analytics and visualization .

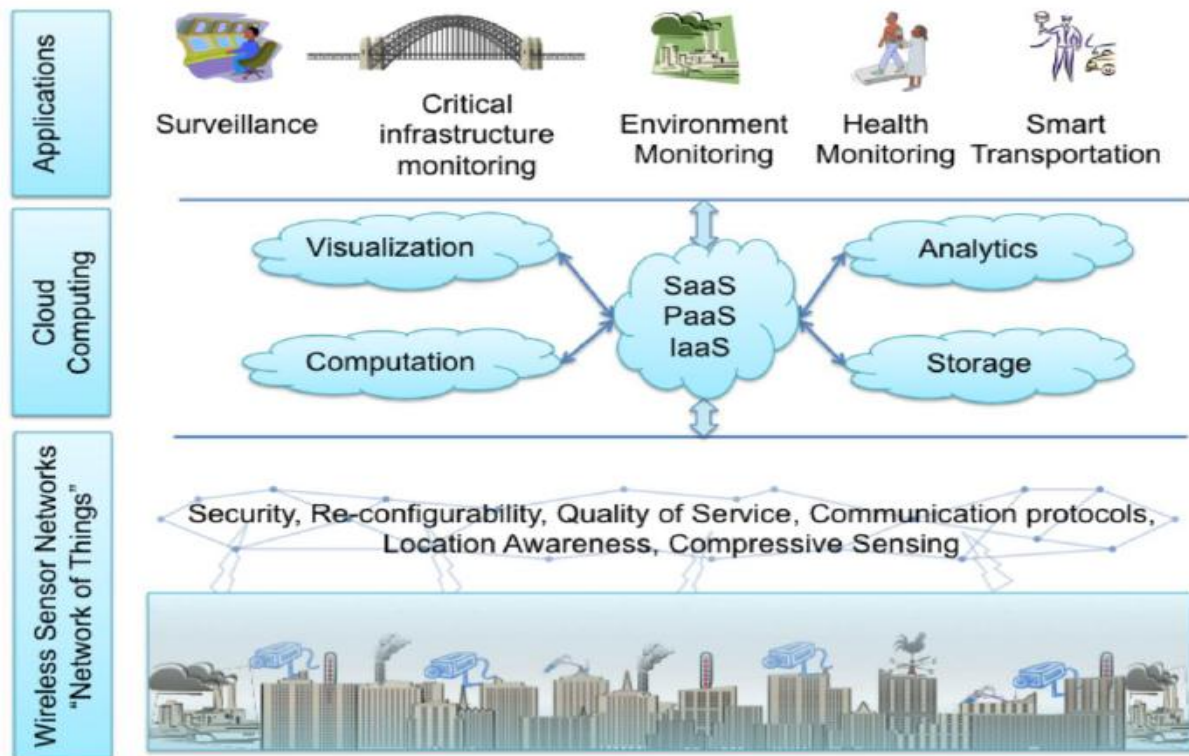


Figure 3: Cloud Computing Framework for IoT(Gubbi, et al., 2013)

IV. CONCLUSION

IoT is becoming a worldwide technology used in every aspect of life that requires large storage and real time computation capability. IoT devices have certain limitations regarding these resources that can be overcome by using Cloud Computing with virtually infinite storage and processing power. In this paper we discussed the characteristics, benefits and limitations of these two emerging technologies that derive the convergence of IoT with Cloud. In future work, a number of real time scenarios will be implemented in different domains to test the effectiveness of this convergence.

V. REFERENCES

- [1] S. M. Babu, A. J. Lakshmi and B. T. Rao, "A study on cloud based Internet of Things: CloudIoT," 2015 Global Conference on Communication Technologies (GCCT), 2015, pp. 60-65.
- [2] P. Mell, and T. Glance, "The NIST definition of cloud computing", Available at: <http://csrc.nist.gov/groups/SNS/cloud-computing/>
- [3] K. Ashton, "That 'Internet of Things' Thing," *RFID J.*, 2009, pp. 49-86.
- [4] G. Joshi and S. Kim, "Survey, Nomenclature and Comparison of Reader Anti-Collision Protocols in RFID," *IETE Tech. Rev.*, vol. 25, no. 5, 2013, pp. 285-292.
- [5] ITU, "Overview of the Internet of things", 2012, pp. 22-40.
- [6] Perera, C., Zaslavsky, A., Christen, P., & Georgakopoulos, D. (2014). Context aware computing for the internet of things: A survey. *IEEE communications surveys & tutorials*, 16(1), 414-454.
- [7] [https://www.kdnuggets.com/2017/05/internet-of-things-iot-cloud.html]
- [8] Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future generation computer systems*, 29(7), 1645-1660.
- [9] Buyya, R., Yeo, C. S., Venugopal, S., Broberg, J., & Brandic, I. (2009). Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility. *Future Generation computer systems*, 25(6), 599-616.
- [10] Armbrust, M., Fox, A., Griffith, R., Joseph, A. D., Katz, R., Konwinski, A., ... & Zaharia, M. (2010). A view of cloud computing. *Communications of the ACM*, 53(4), 50-58.
- [11] Atlam, H., Alenezi, A., Alharthi, A., Walters, R., & Wills, G. (2017). Integration of cloud computing with internet of things: challenges and open issues.
- [12] Miorandi, D., Sicari, S., De Pellegrini, F., & Chlamtac, I. (2012). Internet of things: Vision, applications and research challenges. *Ad hoc networks*, 10(7), 1497-1516.
- [13] Jadeja, Y., & Modi, K. (2012, March). Cloud computing-concepts, architecture and challenges. In *Computing, Electronics and Electrical Technologies (ICCEET)*, 2012 International Conference on (pp. 877-880). IEEE.
- [14] Botta, A., De Donato, W., Persico, V., & Pescapé, A. (2014, August). On the integration of cloud computing and internet of things. In *Future internet of things and cloud (FiCloud)*, 2014 international conference on (pp. 23-30). IEEE.