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A Review on Integration of Cloud Computing and Internet of Things

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Abstract: Internet of things (IOT) is an abstract idea that visualizes all objects that present around us as the part of internet. IOT scope is very wide and includes sensing, communicating and networking of devices deployed that has potential to grow on large scale in future. As processing, storage, and communication capabilities of individual IOT device are limited, the assistance from the current cloud computing technology will help to release the burden, reduce the energy consumption, and prolong battery life. Cloud computing is a model for on-demand access to shared pool of configurable resources that can be easily provisioned for as Infrastructure (IaaS), software and applications (SaaS). The integration of the sensor network with the cloud provides storage and computational resources .This way the scalable network will be reliable and secured.

Keywords: Internet of things (IOT), Cloud Computing, Integration, networking.

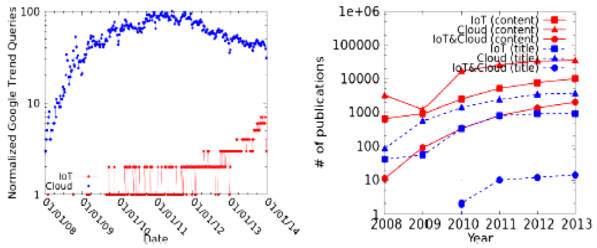
I. INTRODUCTION

IoT, the term first introduced by Kevin Ashton in 1998, is a future of Internet and ubiquitous computing [1]. This technological revolution represents the future of connectivity and reachability. In IoT, 'things' refer to any object on face of the Earth, whether it is a communicating device or a non-communicating dumb object. The objects become communicating nodes over the Internet, through data communication means, primarily through Radio Frequency Identification (RFID) tags. IoT include smart objects as well.. This is why, IoT is not only hardware and software paradigm, but also include interaction and social aspects as well [2]. IoT consists in interconnected devices "things" and their addressable virtual representation using standard communication protocols. The heterogeneity of "things", makes interoperability between them a problem that prevents adoption of generic solutions. Furthermore the volume, speed and volatile data from IoT, impose challenges to existent information services. The will to extend the existent internet with objects, interconnected physical devices and their virtual representation has grown in the last years. This is going to enable the creation of a wide brand of services in different domains, such as smart houses, e-health, transportation, logistics and environmental [3] [4] [5].

Cloud computing allows to rent infrastructure, runtime environments and services in a pay-per-use basis. It can offer different types of solutions based on user's requirements, such as, scaling an enterprise infrastructure on demand and sizing it according to the business needs. In case of end users data will be available anytime anywhere from any device that has a connection to the internet. Cloud Computing is an extremely flexible environment for building new systems and application and even integrating additional capacity or new features into existing systems. Although cloud computing have evolved much its use is still limited to only set of services from a provider The lack of standardization efforts in the past for this technology made difficult move services from one provider to another [6] [7] [8] [9].

II. INTEGRATION OF CLOUD AND IOT

There are large number of papers which propose an integrated usage of Cloud and IoT [10]. As shown in Fig. 1, both topics gained popularity in the last few years (Fig. 1a), and the number of papers dealing with Cloud and IoT separately show an increasing trend since 2008 (Fig. 1b) 1.



(a) Interest from Google research trends. (b) Interest by content and title.

Fig. 1: Research and interest trends about Cloud and IoT [10]

All The two worlds of Cloud and IoT have seen an independent evolution. However, several mutual advantages deriving from their integration have been identified in literature and are foreseen in the future. On the one hand, IoT can benefit from the virtually unlimited capabilities and resources of Cloud to compensate its technological constraints (e.g., storage, processing, energy). Specifically, the Cloud can offer an effective solution to implement IoT service management and composition as well as applications that exploit the things or the data produced by them. On the other hand, the

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Cloud can benefit from IoT by extending its scope to deal with real world things in a more distributed and dynamic paradigm are reported in Tab. I. Essentially, the Cloud acts as intermediate layer between the things and the applications, where it hides all the complexity and the functionalities necessary to implement the latter. This framework will impact future application development, where information gathering, processing, and transmission will produce new challenges to be addressed, also in a multi-cloud environment [11]. In the following, we summarize the issues solved and the advantages obtained when adopting the CloudIoT paradigm manner, and for delivering new services in a large number of real life scenarios. The complementary characteristics of Cloud and IoT arising from the different proposals in literature and inspiring the CloudIoT.

Storage resources: IoT involves by definition a large amount of information sources (i.e., the things), which produce a huge amount of non-structured or semi-structured data [11] having the three characteristics typical of Big Data [12]: volume (i.e., data size), variety (i.e., data types), and velocity (i.e., data generation frequency). Hence it implies collecting, accessing, processing, visualizing, archiving, sharing, and searching large amounts of data [13]. Offering virtually unlimited, low-cost, and on-demand storage capacity, Cloud is the most convenient and cost effective solution to deal with data produced by IoT [13]. This integration realizes a new convergence scenario, where new opportunities arise for data aggregation, integration, and sharing with third parties. Once into the Cloud, data can be treated in a homogeneous manner through standard APIs, can be protected by applying top-level security, and directly accessed and visualized from any place [11].

Computational resources: IoT devices have limited processing resources that do not allow on-site data processing. Data collected is usually transmitted to more powerful nodes where aggregation and processing is possible, but scalability is challenging to achieve without a proper infrastructure. The unlimited processing capabilities of Cloud and its on-demand model allow IoT processing needs to be properly satisfied and enable analyses of unprecedented complexity. Data-driven decision making and prediction algorithms would be possible at low cost and would provide increasing revenues and reduced risks [14]. Other perspectives would be to perform real-time processing (on-the-fly), to implement scalable, real-time, collaborative, sensor-centric applications, to manage complex events, and to implement task offloading for energy saving [15].

Communication resources: One of the requirements of IoT is to make IP-enabled devices communicate through dedicated hardware, and the support for such communication can be very expensive. Cloud offers an effective and cheap solution to connect, track, and manage anything from anywhere at any time using customized portals and built-in apps [13]. Thanks to the availability of high speed networks, it enables the monitoring and control of remote things [13], their coordination, their communications, and the real-time access to the produced data [13].

III. ISSUES IN INTEGRATION OF CLOUD AND IOT

It is not going to be that simple to allow everything become part of IoT and then having all the resources available through cloud computing. There lies some issues that have to be taken care of to allow CoT prevail for the betterment of the world in general and humanity in specific. Other than data and resources, cloud has to deal with the business point of view as well. CoT will create more business opportunities, making it bigger threat from the attackers. Security and privacy specially, identity protection becomes very important in hybrid clouds, where there is an essence of private and public clouds, used by businesses [16]. In CoT, heterogeneous networks will be involved, which support different types of data and services. The network must have the flexibility to support all types of data, according to their requirements, with QoS support [16]. Some of the key issues are discussed below.

A) protocol support

For different things to be connected to the Internet, different protocols will be there in use. Even if there are homogenous entities, for example a sensor IoT, then there is a possibility sensors may be working on different protocols, like: Wireless HART, ZigBee, IEEE 1451, and 6LOWPAN. Some of the protocols will be supported by the gateway device, while some protocols might not have a support. It all depends upon the gateway, as well as the sensor being used. In user's perspective, cheaper or easily available sensor would be a preference. So, it cannot be guaranteed whether a newly added sensor will be successfully configured or not. Solution to this kind of problem may be mapping of standardized protocols in the gateway.

B) Energy efficiency

All With sensor networks everywhere and connectivity with the cloud will lead to a lot of data communication, which consumes a lot of power. A typical wireless is composed of four components: sensing unit, processing unit, transceiver, and power unit. In case of video sensing, video encoding and decoding, power plays a vital role. Normally, video encoding is more complex, as compared to decoding. The reason behind this is that for efficient compression, the encoder has to title and author details must be in single-column format and must be centered. Every word in a title must be analyzing the redundancy in the video [17]. It is not going be suitable to have a temporary power supply, like batteries and have to replace them every now and then. With billions of sensors and low power devices, it is beyond possibility. Having efficient usage of energy and rather permanent power supply would be required. There should be means for sensors to generate power from the environment, like, solar energy, vibration, and air. Also, effective sleep mode can be handy in this regard as well.

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c) Resource Allocation
When IoT's of entirely different and unexpected things would be asking for resources on a cloud, resource allocation would be a challenge. Because it would be very difficult to decide how much a particular resource may be required by an entity or a particular IoT. Depending upon the sensor and the purpose for which sensor is being used, the type, amount, and frequency of data generation, resource allocation has to be mapped. Sending a sample packet from the newly added node can also be useful.

D) Identity management
Communicating nodes over the Internet are identified uniquely. When objects are becoming part of Internet (IoT), they also need a unique identification. Also, in case of mobile devices, like mobile sensor nodes on vehicles and other objects, need to have identity mapping in the new network they have just entered. Since IPv6 address space is believed to be enough to support even this kind of ubiquitous networking, assigning IPv6 addresses can be a more than reasonable way in this regard.

E) IPv6 deployment
If IPv6 is to be used for the identification of communicating objects, then formal deployment of IPv6 would also be an issue. Unless a proper, standardized, and efficient mechanism of IPv4-IPv6 coexistence is adopted, objects being assigned IPv6 would be of no great benefit. Studies focusing on IPv4-IPv6 coexistence and smooth transitioning towards IPv6 must be considered for this problem.

F) Service discovery
With Cloud of Things, the cloud manager or broker has the responsibility to discover new services for the users. In IoT, any object can become part of it at any moment and can leave the IoT at any moment. Some of the IoT nodes may also be mobile. It would be an issue to discover new services and their status and update the service advertisement accordingly. For complex and bigger IoT's, there may be a need of IoT manager as well, which can perform the responsibility of managing the status of IoT nodes, track mobile nodes and keep the updated status of existing nodes and newly added nodes of its IoT. A uniform way of service discovery would be required for this purpose.

G) Quality of Service provisioning
As the amount of data increases and the type and unpredictability also comes into play, QoS becomes an issue. At any moment, any type and amount of data can be triggered. It may also be an emergency data as well. Dynamic prioritization of the requests would be required on cloud side [J Gubbi]. QoS would mostly be measured in terms of bandwidth, delay, jitter, and packet loss ratio. Depending upon the type of data and its urgency to be sent to the sync node, QoS must be supported.

H) Location of data storage
Location also matters for critical and latency or jitter sensitive data. Time sensitive data, like video, should be stored in the closest possible physical location to the user, so that minimum possible time should be involved in accessing big data. For multimedia data, nearest possible virtual storage server must be allocated.

I) Security and privacy
Security and privacy will become more of an issue with the kind of ubiquitous computing we are going to have in future. Data security would be an issue on IoT side as well as on cloud side. Similarly, in terms of privacy, more concern would be there. On Feb 01, 2013, it was read on The Independent [18], stating, "British internet users' personal information on major 'cloud' storage services can be spied upon routinely by US authorities". So, sensitive or private data must also be stored in a virtual storage server located inside the user's country or trusted geographical domain. This can be a friendly country as well.

J) Unnecessary Communication of data
When anything would be able to connect to the Internet and generate data, there is a possibility that at some stage it is no longer necessary to upload the data to the cloud or sync device. data to be sent. This kind of a gateway, we may call it 'smart gateway' would help in better utilization of network and cloud resources.

IV. APPLICATIONS

A) Healthcare
Pervasive healthcare applications generate a vast amount of sensor data that have to be managed properly for further analysis and processing [19]. The adoption of Cloud in this scenario leads to the abstraction of technical details, eliminating the need for expertise in, or control over, the technology infrastructure [20] and it represents a promising solution for managing healthcare sensor data efficiently [19]. It further makes mobile devices suited for health information delivery, access and communication, also on the go, enhancing medical data security, availability, and redundancy [20].

B) Smart City
Smart city setup requires acquiring information from different heterogeneous sensing infrastructures, accessing all kinds of geo-location and IoT technologies (e.g., 3D representations through RFID sensors and geo-tagging), and exposing information in a uniform way. Frameworks can consist of a sensor platform (with APIs for sensing and actuating) and a Cloud platform for the automatic management, analysis, and control of big data from large-scale, real world devices [21].

C) Smart Home and Smart Metering
IoT has large application in home environments, where heterogeneous embedded devices enable the automation of common in-house activities. In this scenario, the Cloud is the best candidate for building flexible applications with only a few lines of code, making home automation a trivial task. In order to let a variety of independent single-family smart homes access reusable services over the Internet, the

resulting solution should satisfy three crucial requirements [22]: internal network interconnection (i.e., every digital appliance in smart home should be able to interconnect with any other), intelligent remote control (i.e., appliances and services in the smart home should be intelligently manageable by any device from anywhere), and automation (i.e., interconnected appliances within the home should implement their functions via linking to services provided by smart-home oriented Cloud).

d) Video surveillance

Intelligent video surveillance has become a tool of the greatest importance for several security-related applications. As an alternative to in-house, self-contained man-agement systems, complex video analytics require Cloud-based solutions (VSaaS [23]) to properly satisfy the requirements of storage (e.g., stored media is centrally secured, fault-tolerant, on-demand, scalable, and accessible at high-speed) and pro-cessing (e.g., video processing, computer vision algorithms and pattern recognition modules to extract knowledge from scenes).

e) Automotive and Smart Mobility

The integration of Cloud technologies with WSNs, RFID, satellite networks, and other intelligent transportation technologies represents a promising opportunity to tackle the main current challenges [24]. A new generation of IoT-based vehicular data Clouds can be developed and deployed to bring many business benefits, such as increasing road safety, reducing road congestion, managing traffic, and recommending car maintenance or fixing [24].

f) Smart Energy and Smart Grid

IoT and Cloud can be effectively merged to provide intelligent management of en-ergy distribution and consumption in both local and wide area heterogeneous environments. In the first case, for instance, lighting could be provided where and when strictly necessary by exploiting the information collected by different types of nodes [24]. Such nodes have sensing, processing, and network-ing capabilities, but limited resources. Hence, computing tasks should be properly distributed among them or demanded to the Cloud, where more complex and comprehensive decisions can be made. the problem on energy alternative and compatible use can be solved by integrating system data in the Cloud, while providing self-healing, mutual operation and participation of the users, optimal electricity quality, distributed generation, and demand response [25].

V. CONCLUSION

This paper discusses about the expanding IoT's and their integration with cloud computing, for enhanced and more useful service provisioning to the user and efficient utilization of resources. This integration involves some key challenges as well, which have been discussed in this paper. More study on the impact of these issues, specially, keeping in view the type of IoT and type of service being provided, can be done in the future. Some of the data being generated by a specific IoT may require special type of storage and momentarily, the data may not be required. In that scenario, that either the device must be stopped from generating data or gateway device must device when it is required to stop uploading the data and not to consume resources of the network and cloud for that while. It will also help in efficient utilization of power. For this purpose, the gateway device, connecting IoT to the cloud, should be having extra functionality to do a little processing before sending it to the Internet and eventually to the cloud. Based on the feedback from application, gateway must decide the timings and type of development of application on it. This can as well be a potential future work in this regard.

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