Architecture Proposal for MCloud IoT

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Abstract. The world is now heading towards an era shaped by things that able to act and interact through Internet. Despite of many IoT devices suffer from limitations regarding to storage, processing capability, and communication, IoT plays a major role providing a new set of applications and services. Cloud computing provides a supplement solution for IoT limitation. Integration of IoT and Cloud Computing is considered a new direction that both scientist and business are seeking for bringing new applications and benefits to existing applications and services. Moreover, the fast development of mobile devices produces powerful devices that are able to play many roles, creating better IoT scenarios. In this paper; we propose a new MCloud IoT architecture that works on an IoT environment, which is composed by mobile devices such as smart phones, tablets, and smart sensors. MCloud IoT architecture is designed to deliver the applications and services demanded by end users. Moreover, we have included a layered communication model for devices' communication. In our design we have taken into account the system performance and to provide QoS. We also analyze the benefits of our design. This new architecture provides a revolutionary vision that meets the future expectations of cloud systems.

Keywords: IoT · Cloud computing · Cloud of things · Cloud IoT architecture · Mobile devices

1 Introduction

The world is heading towards a new era (anything, anytime, anywhere) shaped by the Internet and things that have the ability to act and react through data [1]. This leads to massive transformation of almost every aspect in people's lives; the ways they act, learn, communicate, create new things, etc. Moreover, this evolution produces new technologies and paradigms which open even more opportunities and chances to pave the way to the shifting towards the smart things and services.

Internet of Things (IoT) paradigm is one of the key building block of this era, in this paradigm real objects called 'things' are smart enough to connect each other and to other systems and then to Internet. IoT provide many applications and services in addition of enabling ubiquitous computing. But things have some limitations in matter of storage and process capacity in complex computation [2].

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Cloud computing is a technology that provides virtually infinite resources for data storage and processing. Cloud computing provides this through several services such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) where end customers can choose easily the service to satisfy their needs [3]. Recently, there are appearing many task scheduling algorithms for cloud environments [4], which allow them to have high performance. Moreover, there are also appearing cloud systems to provide live video streaming [5].

IoT and Cloud computing are attracting a lot of attention despite of the differences between them. Many researchers believe that they are complementary and that may lead to new application scenarios in addition to improve the current ones. This line of researches toward the integration of IoT and Cloud computing have been referred as Cloud of Things.

Cloud of Things is a new paradigm which integrates IoT and Cloud Computing. It provides the features of ubiquitous IoT applications and services, and can be applied to smart homes, smart cities, health care, smart logistic, etc., in order to facilitate the end user life. It allows reaching anything anywhere at anytime, without taking care of where to store their data and how to perform any operation with no matter about the requirements of processing capacity or resources thanks to Cloud Computing. Cloud of Things should easily be able deliver IoT services, introduce specific performance, and QoS requirements to meet users demands.

The number of connected devices (especially smart mobile devices) is increasing continuously. In addition, they are massively spreading around the world. This number exceeds more than 10 billion and it is expected to reach 24 billion in 2020. That will lead to generate massive amount of data too. These data will require efficient ways to gather, store, process and extract knowledge from it. However, Cloud of Things using mobile phones is in its early stage, which means that a lot of work and research should be done to address different issues and challenges.

This paper aims to develop a new MCould IoT architecture; that works on IoT environment, which is composed of mobile devices such as smart phones, tablets, smart sensors, to deliver the application and services demanded by end users. In our design we have taken into account the system performance and to provide QoS.

This paper is structured as follows. Section 2 describes the related works. Section 3 presents the proposed MCloud IoT architecture. Section 4 describes the difference between our MCloud IoT proposal and a regular Cloud for IoT. We conclude this paper in Sect. 5.

2 Related Work

There are few works published about Cloud IoT. Some works address the integration of IoT and Cloud computing, but they still do not provide any detailed system or a standard solution to the challenges and issues of the area. Next, we describe the related works we have found.

In [6], authors present a Smart Gateway based communication plus Fog computing to offer smart communication with little computation overhead on core network. They handle real-time and delay sensitive applications by trimming and pre-processing the data before sending it to the cloud. Based on the tests performed of various performance parameters they believe that their proposed architecture will deliver a rich portfolio of services.

The authors of [7] proposed an architecture for Cloud of Things for sensing as a Service. The aim of the authors was to perform an in-network distributed processing system and an efficiently set up virtual sensor network on the top of a subset of the pre-selected IoT devices in order to provide a global platform for data analysis and decision making. Their proposed algorithms can realize virtual sensor networks with minimal physical resources, low complexity, and reduced communication overhead.

In [8], a conceptual platform and the defined key characteristics of Fog computing are presented. It is considered the appropriate platform for a number of critical IoT, where services and applications are handled at the edge of the network.

A Cloud provisioning model is proposed in [9]. It is an architecture designed to leverage from bridging Clouds with the IoT to meet user needs according to some guaranteed service levels. It also introduces things as infrastructure for Cloud like exploitation. Authors tried to address the ideas of the intersections between them where heterogeneous resources should be combined and abstracted according to tailored thing-like semantics paving the way for innovative and value-added services.

In [10], authors implement and test the behavior of a health monitoring system in the context of clouds and IoT. They introduced SimIoT toolkit with the utilization of short range and wireless communication devices to meet dynamic information processing where IoT devices schedule requests for services in private clouds.

The authors of [11] proposed an architecture model for medical information using IoT and cloud computing integration through the combination of technology monitoring and management information system of a hospital. Moreover, an effective algorithm is proposed for the medical monitoring application. The proposed remote monitoring cloud platform architecture model has been evaluated through an experimental analysis and simulation.

In [12], authors propose a smart gateway communication system for Cloud IoT architecture. The study aims to enhance service provisioning to the user and efficient utilization of resources using a smart gateway that performs several tasks such as data trimming and pre-processing before sending them to the cloud. In addition, they use Fog computing to alleviate the burden of the cloud. The paper also shows that normal communication can be made in real-time for delay sensitive applications.

The architecture proposed in [13] provides a simple, energy efficient, flexible, and secure scheme for a smart house based on Cloud of Things (CoT). The proposal ensures the security to transfer data through the proposed mechanism for smart housing. They consider different types of devices and their capabilities, the scalability of the smart house and the energy consumption.

In [14], a Model Driven Architecture (MDA) is used to develop Software as a Service (SaaS) to facilitate the mobile applications development by relieving developers from technical details.

The work shown in [15] aims to provide efficient access controls and sharing controls with slight virtualization overhead for a cloud of things architecture. Authors propose an Evolvable Cloud of things (ECO) middleware that makes use of a lease-based sharing control mechanism for enabling logical isolation and efficient sharing between multi-tenant applications through virtualization. The validation of the system performance confirmed that it reduces the effort and complexities when implementing and developing applications. The system also provides and effective sharing with a little virtualization overhead.

Along the reviewed related literature we have not seen any designed system that integrates mobile IoT devices and cloud computing.

3 MCloud IoT Architecture

Integration of IoT and Cloud computing is considered a new direction that both scientist and business seeking for and interest about to bring new applications and benefits to existing applications and services. Nowadays there are many powerful mobile devices (smart phones tablets, and even sensors) acting as things in Internet [16]. They gather data from the surrounding environment and store them locally or remotely for further processing. They exist in any environment, composing one of the best IoT scenarios. These devices can offer different services such as storage resource, a processing capability, a gateway to other network and/or Internet. On the other hand, the fact of having a cloud for the data and services of these devices include many constraints, which brings the need of research for providing Cloud IoT solutions based on the idea of those mobile devices to create a cloud.

The proposed MCloud of Things architecture allows mobile users to create their own cloud using a Cloud IoT application which implements the cloud agent in their devices. Then the users will be able to access the shared resources in the cloud such as storage, run some tasks, with certain specifications, virtually on any other mobile devices in IoT environment as shown in Fig. 1.

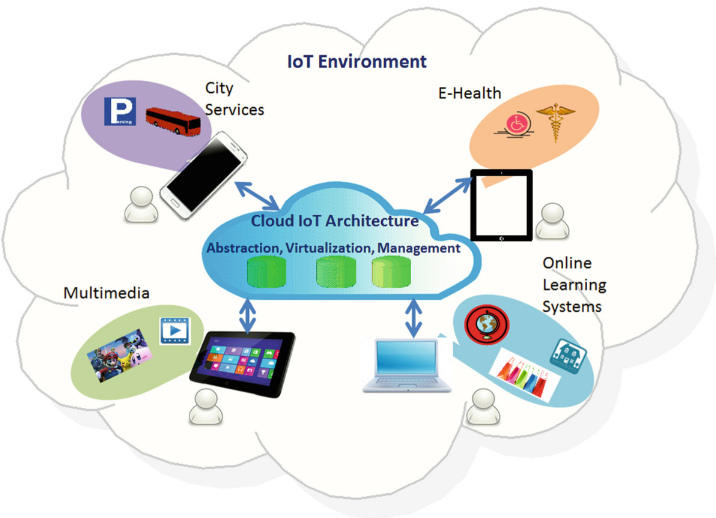

Fig. 1. Overview of MCloud IoT architecture.

3.1 Conceptual Layers View of MCloud IoT Architecture

The conceptual view of the proposed MCloud IoT architecture structure form 3 main layers as shown in Fig. 2:

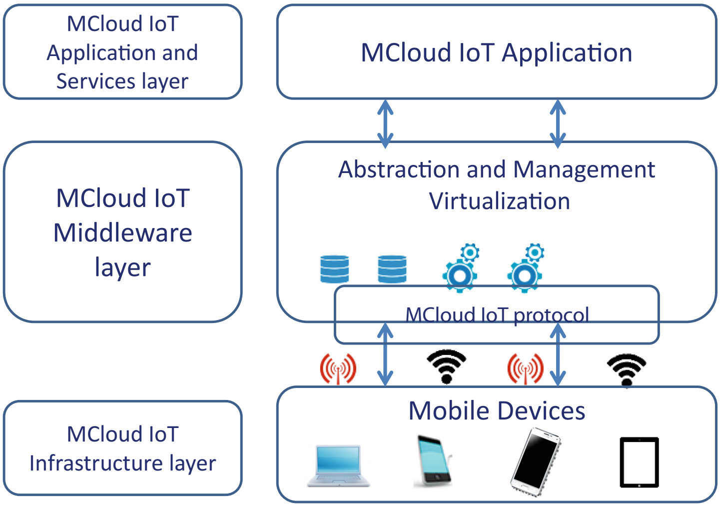

Fig. 2. Conceptual layers view of cloud IoT architecture.

- Infrastructure layer that handles the heterogeneity of the mobile devices;
- The middleware layer that is responsible of managing the resources of the cloud (virtualizes the resources, determines the roles of each device, extracts the resources of the tracking the status). It also contains the cloud agent which responsible of arranging the service such as resource identification resource discovery, transform the data into generic form to store it into the cloud and/or deliver it to other devices through the cloud. The application layer that contains the MCloud IoT application. It is the interface with the new cloud or other IoT application and services that will used by the devices participating into the MCloud IoT, such as resource allocation, perform processing, or deliver new services.

MCloud IoT architecture will help in managing IoT resources, allowing delivering new services to end user; for example providing the services from different devices and environment into the cloud will simplify the service delivery in IoT environment because in this case it will have an ubiquitous access for the users and it will extend the usage of the service into larger section of user.

The future rely on mobile devices as a key element to access, control, store, and mange different data through large set of applications that serve wide range of people needs. So, it will be a promising line to work more in the capabilities of these devices.

Users require more and more storage to store their data, more processing capacity to perform complex task. They want to be online everywhere at anytime. In order to achieve this expectation, new architectures and mechanisms are required.

A closer look into the IoT architecture layers is illustrated in Fig. 3. Things layer is the lowest layer and it represents different objects that perceive data from the surrounding environment such as mobile devices, sensors, objects with RFID tag,…

Connectivity layer: it is similar to network layer in OSI model. It includes a gateway to transfer the collected data into next layer through variety of wireless technologies and communication protocols such as Wifi, NFC, and Bluetooth. Thus, it has one interface connected to the things network and another to Internet.

Middleware layer: it provides an abstraction for the underlying infrastructure, dealing with different issue according to the heterogeneity, it responsible of service management such as service identification and discovery, tacking the status of the devices. It also handles the context management of the data.

Service layer: its purpose is to provide cloud services to the data such as storage of data, perform information processing and take decisions. In addition to that, it protects the data using suitable security mechanisms. It passes the output to the next layer.

Application layer: it presents the final form of data. It can process the data for large number of applications in different areas such as smart home, health care, etc.

Fig. 3. IoT architecture

3.2 MCloud IoT Architecture Components and Functionalities

The new MCloud IoT architecture works on IoT scenario considering mobile devices as things of that environment. We call it Mobile Cloud IoT or MCloud IoT.

The components for new MCloud IoT architecture are shown in Fig. 4:

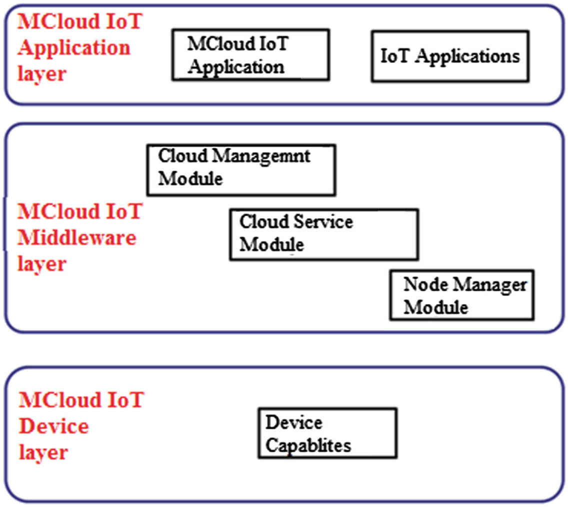

Fig. 4. MCloud IoT architecture components

- **The MCloud IoT application**: it is a mobile application installed into the mobile devices such as smart phones, tablets, laptops; it represents an interface to the MCloud IoT middleware.
- **The MCloud IoT middleware**: it is responsible of providing the abstraction and management through a number of modules describes as follow:
  - **The Node manager module**: responsible of determining the device role (master, resource provider, gateway), status (active or not), type of communication protocol.
  - **The cloud service module**: it is in charge of the identification of the resource such as resource discovery, resource allocation, storage resource, computing resource, communications resource, and other services defined by cloud users.
  - **The cloud management module**: it is responsible of monitoring the resources, cloud services and other components.
- **The MCloud IoT device layer**: it is responsible of determining the connected devices capacities such as CPU, RAM, and storage.

The proposed architecture is created in a form of wireless ad hoc network, thus, the users should install the MCloud IoT application to be able to implement the proposed architecture and then use it. The application implements the proposed protocol that allows the device to join the cloud and thus discover the services and resources provided on it, after that, it can choose the suitable service based on its needs.

The new MCloud IoT platform also allows the participation of devices to connect to other networks and transfer the data to/from them, even if one device doesn't have a direct gateway to that network. The MCloud IoT will assign one of the devices to act as a gateway for the request device. The new architecture will help in developing new application scenarios that benefit of the capabilities of mobile devices.

There are number of issues that may face the proposed architecture and it has to take into account developing it. These issues such as the heterogeneity of devices, protocol support, how this kind of cloud will interact with other existing clouds, resource allocation, resource identification, security and privacy, reliability, QoS provisioning will examine and cover in the development of the MCloud IoT architecture.

4 MCloud IoT Vs Regular Cloud for IoT

While a regular Cloud for IoT is a Cloud created by servers placed in Internet which store data from the things and provide services to them, a MCloud IoT is a cloud formed by the mobile devices acting as things in Internet. These concepts provide clear differences between their features and the environments where they can be more useful. In Table 1, we provide the main differences. We can observe that MClould IoT will benefit to those systems where the latency and jitter are critical.

Table 1. Comparison between MCloud IoT and regular cloud for IoT

	MCloud IoT	Regular cloud for IoT
Computing capacity	Regular	Very high
Energy/battery	Few	Very high
Storage	Regular	Very high
Bandwidth	Regular (the bottleneck is the "things" connection)	Regular (the bottleneck is the "things" connection)
Latency	Low	High
Jitter	Low	High

It is well known that the most critical issues in cloud computing are its high delay and jitter values [17, 18]. E.g. there are several works [19] that show the average delay for some cloud gaming systems (between 135–240 ms. in some cases and between 400–500 ms. in others), but some well-known cloud providers provide quite higher latency values (e.g. measures shown in [17] range between 2.52 and 8.59 s).

Several measurements in IoT systems show that their latency is quite lower. E.g. In [20], all topologies measured have lower average latency than 400 ms, and in [21], authors measured median end-to-end latency between 500–700 ms. So we can consider them as the worst values. Moreover, it is expected that 5G will benefit IoT since its purpose is to provide an average latency of 1 ms.

In order to compare the latency time in MCloud IoT and regular Cloud for IoT, for comparison purposes, we split the latency of the Round Trip Time (RTT) as the Network Delay (ND) plus the Processing Delay (PD). Other delays (OD) like data gathering delay and frame transmission delay are equal in both cases or close to zero. The equation is as follows:

$$RTT = ND + PD + OD \tag{1}$$

Although the processing delay is lower in the servers provided by a cloud computing service provider than in the mobile devices, we observe in works shown before that the difference of the network latency is quite higher. Taking into account the processing delay at different bandwidths given by Cisco at [22], servers process the information in an order of microseconds, while mobile devices process the data in an order of milliseconds. Figure 5 shows the latency of the compared systems when the packet sizes have 64 Bytes (there are few gathered IoT data per second). We can see that regular Cloud for IoT have higher values than MCloud for IoT. Just the best case of regular cloud for IoT has RTT values in the range of MCloud IoT.

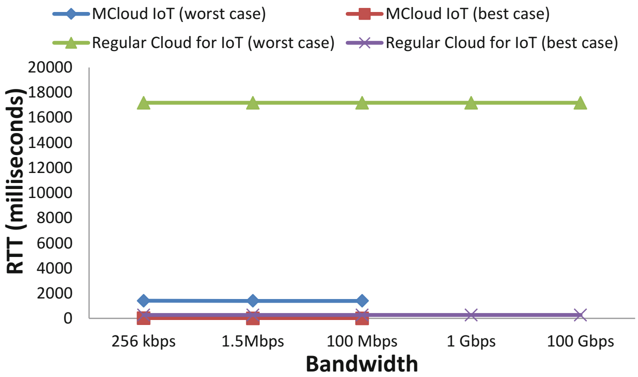

Fig. 5. Latency comparison between MCloud IoT and regular cloud for IoT

5 Conclusion

The integration of IOT and cloud computing is an opening research line and there are some good architectures had been proposed for Cloud IoT. However, they didn't meet the future needs for ubiquitous computing. This paper propose a new MCloud IoT architecture where the things are the mobile devices with ability to build their private cloud taking advantages from their available resources to overcome IOT traditional limitations. Additionally, they are capable to communicate with the neighbor clouds and/or clouds in the internet.

To Implement this architecture a communication protocol will be needed and it is planned as our next step toward illustrate the data flow in the architecture. Combined together with the new architecture the heterogeneity issues will be overcome to enable easy delivering of IOT applications and services in certain scenarios. Moreover, in future work we will add certificate algorithms to secure the system [23, 24].

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