Cloud of Things: Integration of Cloud Computing and IoT

Spandan Jain
Student, TIMSCDR

Afzal Khan
Student, TIMSCDR

Gajendra Dixit
Asst. Professor, TIMSCDR

ABSTRACT
Cloud computing is a major pattern for large data storage and analytics. The combination of cloud computing and IoT can allow the resource sharing more proficiently than individually handling them. In distributed systems, the resources are labelled as cloud services and handled in a centralized way. However, new challenges arise when integrating cloud with IoT. This paper offers the architecture for integrating of cloud computing for Internet of Things and its issues. Cloud computing has long been recognized as an exemplar for big data storage and analytics. The combination of cloud computing and IoT can enable omnipresent sensing services and powerful processing of sensing data streams beyond the capability of individual "things", thus stimulating improvements in both fields. With the trend going on in ubiquitous computing, everything is going to be connected to the Internet and its data will be used for various progressive purposes, giving rise to not only information from it, but also, knowledge and even wisdom. Internet of Things (IoT) becoming so pervasive that it is becoming vital to integrate it with cloud computing because of the amount of data IoT's could generate and their requirement to have the privilege of virtual resources consumption and storage capacity, but also, to make it possible to create more usefulness from the data produced by IoT's and develop smart applications for the users. For instance, cloud platforms permit the sensing data to be stored and used intelligently for smart monitoring and actuation with the smart devices. Artificial intelligence techniques and machine learning procedures can be implemented and run centralized or distributed on the cloud to attain automated decision making. These will boost the evolution of new applications such as smart cities, and transportation systems.

Keywords
Cloud of Computing; Internet Things (IoT); big data; CoT

1. INTRODUCTION
The next milestone in the era of computing will be outside the empire of the traditional desktop. In the Internet of Things (IoT) exemplar, many of the objects that surround us will be on the network in one form or another. Sensor network technologies and Radio Frequency Identification (RFID) will rise to encounter this new dare, in which information and communication systems are invisibly entrenched in the atmosphere around us. This leads to the generation of enormous amounts of data which have to be deposited, processed and presented in a continuous, efficient, and easily interpretable form. This model will contain services that are commodities and conveyed in a manner similar to traditional commodities. Cloud computing can offer the virtual infrastructure for such utility computing which integrates analytics tools,

monitoring devices, visualization platforms, storage devices and client delivery.

Smart connectivity with prevailing networks and context-aware computation using network resources is a crucial part of IoT. With the growing presence of Wi-Fi and 4G-LTE wireless Internet access, the progress towards ubiquitous information and communication networks is already evident. For technology to disappear from the consciousness of the user, the Internet of Things demands: (1) a shared understanding of the situation of its users and their appliances, (2) software architectures and pervasive communication networks to process and convey the contextual information to where it is relevant, and (3) the analytics tools in the Internet of Things that aim for autonomous and smart behaviour. With these three fundamental grounds in place, smart connectivity and context-aware computation can be accomplished.

The term Internet of Things was first invented by Kevin Ashton in 1999 in the perspective of supply chain management. However, in the past decade, the meaning has been more inclusive covering wide range of applications like healthcare, transport, etc. Although the description of 'Things' has changed as technology evolved, the main objective of making a computer sense data without the help of human intervention remains the same.

Fuelled by the occurrence of devices enabled by open wireless technology such as Bluetooth, RFID, telephonic data services, and Wi-Fi as well as embedded sensor and actuator nodes, IoT has paced out of its infancy and is on the verge of altering the current static Internet into a fully unified Future Internet. The Internet revolution led to the interconnection between people at an exceptional scale and pace.

The next revolt will be the interconnection betweenobjects to create a smart environment. In 2011 only did the figure of interconnected devices on the planet overtake the actual number of people.

A schematic of the interconnection of objects is shown in Figure 1, where the application domains are selected based on the scale of the impact of the data produced. The users range from individual to national level organizations addressing wide ranging issues.

Figure 1.Internet of Things schematic showing the end users and application areas based on data.

2. CLOUD COMPUTING

Cloud computing is a system to share resources. Now days, cloud computing is also useful in IT, where the user doesn't needs to worry about maintenance and managing the resources. Cloud computing retrieves the information from the internet using the web-based tools and applications. Cloud computing also provides services. The service models of cloud computing are:

- **Software as a Service (SaaS)**: It offers the universal access to sensor data.
- **Platform as a Service (PaaS)**: The ability provided to the consumer is to organizeonto the cloud infrastructure consumer created or acquire applications formed using programming languages, services, libraries and tools supported by the provider.
- **Infrastructure as a Service (IaaS)**: The skill provided to the customer is forprocessing, storage and other computing resources where the customer can organize and run random software, which can contain operating systems and applications.

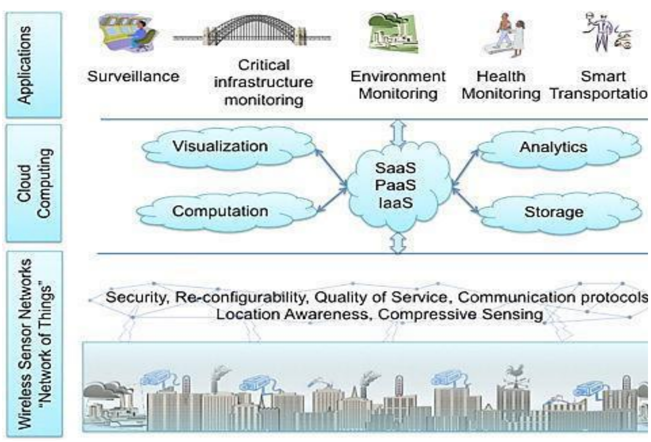

Figure 2. A figure containing the service models of cloud computing.

However, evolving IoT applications using low-level Cloud programming models and interfaces such as Thread and MapReduce models is difficult. To overcome this, we need a IoT application specific framework for rapid creation of applications and their deployment on Cloud infrastructures. This is attained by mapping the proposed framework to Cloud APIs offered by platforms such as Aneka. Hence, the new IoT application specific framework should be able to offer provision for:

- Reading data streams either from sensors directly or procure the data from databases,
- Easy expression of data analysis logic as functions that process data streams in a translucent and scalable manner on Cloud infrastructures, and
- If any events of interest are identified, results should be passed to output streams, which are connected to a visualization program.

Using such a structure, the developer of IoT applications will be able to harness the power of Cloud computing without knowing low-level details of making reliable and scale applications. A model for the realization of such an environment for IoT applications is shown in Figure, thus reducing the time and cost involved in engineering IoT applications.

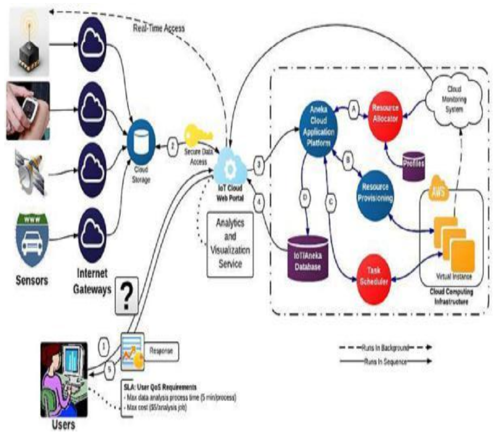

Figure 3. Cloud programming models and interfaces.

3. INTERNET OF THINGS

To communicate and create a ubiquitous replicated-objective world, there has been an increasing interest in the ability of embedded devices, sensors, actuators. To create a persistent connection of "things or nodes" across the network, the growth of the concept of the IoT and rapid growth of technologies such as short-range mobile communication and improved energy efficiency is expected.

For big data storage and analytics, a Cloud computing concept has been recognized. We can enable omnipresent sensing services and powerful processing of sensing data streams beyond the capability of individual things by the incorporation of IoT and cloud computing.

Thus, inventions are stimulating in both fields. For example, cloud platforms permit the sensing data to be stored and used intelligently for smart monitoring and actuation with the smart devices. To accomplish automated decision making a cloud, novel data fusion algorithms, artificial intelligence techniques and machine learning methods can be implemented and run as centralized or distributed.

IoT will boost the progress of new applications such as smart cities, grids, and transportation systems. During the incorporation, QoE and QoS, as well as, privacy, reliability and data security are considered as the critical concerns. The incorporation of cloud computing and IoT requires high quality for these type of issues. With respect to the high-quality on integration of IoT and cloud includes some topics of benefits, the following categories:

- Appropriate Network architecture with supported protocols for IoT and cloud integration.
- Data communication management between cloud and IoT.
- Machine to machine communication sharing in cloud.
- Appropriate design and modifications with respect to protocols in the integration of cloud and IoT(e.g., CoAP, IPv6).
- Proper sharing of ubiquitous sensing services and applications in cloud environment.
- Security, privacy and reliability of data in IoT and cloud integration.

The Architecture of IoT is usually considered to be 3-layer, with Perception layer, Network layer, and Application layer, but Middleware layer and the business layer can add[7][8].

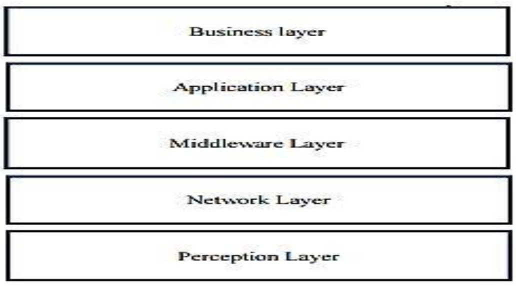

Figure 4:Five-layer architecture

3.1 Business layer
It is subjected to making money by processing the results or services received from application layer. For controlling of IoT system comprising the applications and services are accountable for the business layer.

3.2 Application layer
Application layer couple’s business services and offers servicesto the end user (Web Service, UI, etc.). The application layer links the gap between the business layer and the boundary technology.

3.3 Perception layer
This layer can be used for sensing components or nodes, actuator components or nodes. Sensing components include RFID, sensors, bar code label, meters and intelligent detection instruments etc. Actuator Components include relay, valve switch, etc. Sensing components and actuator components recognize signal acquisition and control functions. The collected information is despatched to the Network layer for secure transmission.

3.4 Network layer
Network layer includes various bus such as the RS- 485 bus, the controller area network (CAN) bus, etc., or wireless network such as wireless sensor network (WSN), Wi-Fi, Bluetooth, etc. It recognises communication connection between perception components, or between IoT gateway and perception components.

3.5 Middleware layer
Middleware layer lies between application layer and network layer and it receives the data from network layer and it forms decisions based on the performed results and send that results to application layer. Managing services and data storage is the main function of this layer. This layer is accountable for the service management and has link to the database.

4. INTEGRATION OF CLOUD COMPUTING AND INTERNET OF THINGS
IoT can benefit from the virtually unlimited abilities and sources of Cloud to compensate its technological constraints (e.g., garage, processing, strength). Basically, among the nodes and the applications, the Cloud acts as intermediate layer. a number of the issues can be solved, and the advantages can be received when adopting the CoT idea. Because the range of linked devices elevated, extra information is required. To store big amount of information large space, and greater processing is wanted. More processing isn't possible with IoT. Greater processing and computation are most effective possible with cloud computing. Cloud computing offers effective solution to put into effect IoT provider control and composition. The cloud can provide actual way to put into effect IoT service management and composition as well as applications that exploit the information shaped by means of them. Additionally, the Cloud can advantage from IoT by way of spreading its possibility to deal with actual real world things in a more dispensed and active way, and for bringing new facilities in a great number of real life situations. Cloud computing and IoT processing in integration makes an orientation

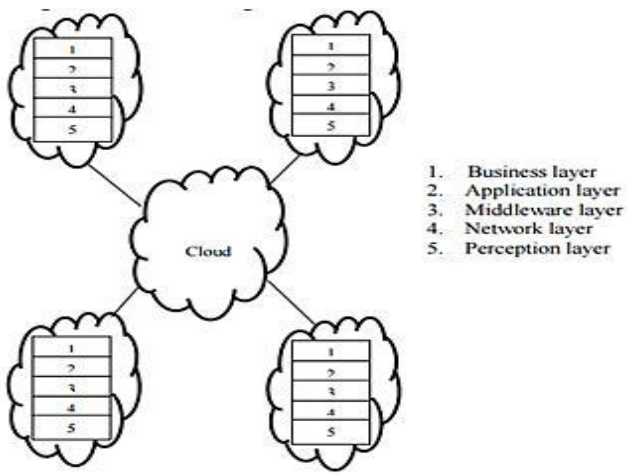

Figure 5. Data communication between cloud and IoT

The adoption of the CoT concept enables new scenarios for smart services and applications based on the extension of Cloud through the things [3][4]:

- **SaaS (Sensing as a Service), [**3] [5] [1**]** providing ubiquitous access to sensor data.
- **SAaaS (Sensing and Actuation as a Service), [3]** enabling automatic control logics implemented in the Cloud.
- **SEaaS (Sensor Event as a Service),** [3] [1] dispatching messaging services triggered by sensor events.

- **SenaaS (Sensor as a Service),** [5] enabling ubiquitous management of remote sensors.
- **DBaaS (DataBase as a Service),** [5] enabling ubiquitous database management.
- **DaaS (Data as a Service),** [5] providing ubiquitous access to any data.
- **EaaS (Ethernet as a Service),** [5] providing ubiquitous layer-2 connectivity to remote devices.
- **IPMaaS (Identity and Policy Management as a Service),** [5]enabling ubiquitous access to policy and identity management functionalities.
- **VSaaS (Video Surveillance as a Service),** [2] providing ubiquitous access to recorded video and implementing complex analysis in the Cloud.

5. PROTOCOLS USED IN CLOUD OF THINGS

CoAP (Constrained Application Protocol)

It is used to interact with Things in the Cloud of Things architecture. This protocol is similar to the HTTP protocol, and it offers request/response interaction model between the application end-points. Both HTTP and CoAP protocols are based on same client/server model, and both are denoted by same interaction model. The CoAP protocol interchange the messages asynchronously over User Datagram Protocol (UDP), and to regain the resources from telematics devices or WSN nodes GET method is used. In order to modify the existing resource on a sensor node, or a telematics device PUT method is used. With the Representational State Transfer (REST) methods of GET, PUT, DELETE, POST resources are requested and recognised by the URIs. This protocol also delivers a high level of communication security.

6LoWPAN (Low Power Wireless Area Networks)

This protocol is IPv6based protocol. The invention of 6LowPAN protocol is to provide IP access to a extensive set of networked devices, and it is economical. By means of cross-layer optimization approach, 6LoWPAN can decrease the IPv6/UDP header while preserving the main functionalities and the size of the addressing space. It is also supported for routing functionalities that are offered by the Routing Protocol for Low Power and Lossy Networks (RPL).

6. ISSUES OF CLOUD OF THINGS

It is not so easy to allow everything become part of IoT and then consuming all the resources available for cloud computing. There are some troubles to be taken care of while combining cloud and IoT. Problems regarding the Cloud of Things are protocol support, Energy Efficiency, Service discovery, Resource allocation, Quality of Service provisioning, Location of data storage, Security and privacy, Unnecessary communication of data, identity management and IPv6 deployment,. These issues are discussed below.

A. **Protocol Support:**In similar entities, variousdifferent protocols must be used fordifferent things to connect to the Internet, for instance, consider a sensor IoT, which may functioning on different protocols like ZigBee, WirelessHART and 6LoWPAN. Here gateway device offers support for some protocols and for some protocols it might not have any support. Solutions can be specified for this problem may be by mapping of standardized protocols in the gateway device.

B. **Energy Efficiency:**The main problem of cloud architecture is Energy Efficiency and thisitself becomes an issue in Cloud of Things. Data communication between sensor networks and cloud takes much power. A wireless is composed of four components such as processing unit, sensing unit, power unit and transceiver. Power plays an significant role in case of video sensing, video encoding, and decoding. Usually, as compared to decoding, video encoding is more challenging and reason for this is an efficient compression, the encoder has to analyse the redundancy in the video, and this is not appropriate for low power entities such as batteries. For large number of sensors an efficient usage of energy and permanent power supply would be essential.

C. **Resource Allocation:**Resource allocation is a very tough challenge when differentIoTs and unexpected things would be querying for resources on a cloud. Because it is very difficult to choose what resources to be allocated for any particular IoTs. Resource allocation has to be mapped depending upon the sensor and the reason for which sensor is being used, the amount, type and frequency of data generation.

D. **Identity Management:** When the objects are becoming part of an internet (IoT), they have to communicate with each other, and these objects need to be recognised with a unique identifier. It will be valuable to communicate with objects that are in different network pool. The IPv6 address space is also support for this kind of omnipresent networking.

E. **Security Discovery:**In Cloud of Things, the cloud manager has the duty todiscover new services for the users and in IoT, any object can become portion of it at any moment and can leave the IoT at any moment. To discover new services and their status and to update the service advertisement is becoming an issue in CoT. For handling the status of IoT nodes, track nodes, and keep the status updates of existing nodes, as well as newly added nodes of IoTs, a uniform way of service discovery approach is required.

F. **Quality of Service:** Provisioning the type and unpredictability come into picture as theamount of data increases and alsoQoS (Quality of Service) becomes an issue. Depending upon the category of data and its urgency to be sent to the sync node, QoS must be supported.

G. **Location of data storage:**Time sensitive data, like video, should be stored in thenearest possible physical location to the user, so that least possible time should be involved in retrieving big data. Location also counts for critical and latency sensitive data. Nearest possible virtual storage server must be assigned for multimedia data.

H. **Security and Privacy:**Data security would be an issue on IoT side as well as on cloudside. In terms of privacy, sensitive or private data must be kept in a virtual storage server located inside the user's country or trusted domain.

I. **Unnecessary Communication of data:**At some stages, it is no longer essential toupload the data to the cloud or sync device when anything would be able to connect to the Internet and to generate data.

7. CONCLUSION

This paper describes cloud computing and IoTs and the integration IoT with cloud computing for enhanced service provisioning, data storage, and better utilization of resources. This working procedure of integration is termed as Cloud of Thing (CoT), which discussed how IoT and cloud architectures are communicated with each other in an efficient manner, and also some extended services. In this paper, we discussed some important issues with CoT paradigm. Adapting standardized solutions for those issues is a future and potential work of this paper.

8. REFERENCES

[1] S. K. Dash, S. Mohapatra, and P. K. Pattnaik. "A Survey ofApplication of Wireless Sensor Network Using Cloud Computing". *International Journal of Computer Science& Engineering Technologies* 1(4) (2010) 50-55.

[2] A. Prati, R. Vezzani, M. Fornaciari, and R. Cucchiara. "Intelligent Video Surveillance as a Service". *In Intelligent Multimedia Surveillance,* pages 1-6, Springer, 2013.

[3] B. P. Rao, P. Saluia, N. Sharma, A. Mittal, and S. V. Sharma. "Cloud computing for Internet of Things & sensing based applications". *In Sensing Technology (ICST), 2012Sixth International Conference* on, pages 374-380. IEEE, 2012.

[4] G. Suciu, A. Vulpe, S. Halunga, O. Fratu, G. Todoran, and V. Suciu. "Smart Cities Built on Resilient Cloud Computing and Secure Internet of Things". In Control Systems and Computer Science (CSCS), *19th International Conference on, pages 513-518.* IEEE, 2013.

[5] Zaslavsky, C. Perera, and D. Georgakopoulos. "Sensing as a service and big data". arXiv preprint arXiv:1301.0159, 2013.

[6] Yen-Kuang Chen, "Challenges and Opportunities of Internet of Things", in the proceedings of *17th Asia and South Pacific Design Automation Conference,* 30 Jan. – 02 Feb., 2012, Santa Clara, CA, USA.

[7] Dave Evans, "The Internet of Things How the Next Evolution of the Internet Is Changing Everything", Whitepaper, Cisco Internet Business Solutions Group (IBSG),April 2011.

[8] Mell, P. &Grance, T., 2011, "The NIST Definition of Cloud Computing", NIST Special

[9] Gartner cloud computing definition, http://www.gartner.com/itglossary/cloud-computing/

[10] AlessioBotta, Walter de Donato, Valerio Persico, Antonio Pescap´,"On the Integration of Cloud Computing and Internet of Things". *The 2nd International Conference onFuture Internet of Things and Cloud (FiCloud-2014),* August 2014, Barcellona, Spain.