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A Cloud Platform for the Internet of Things

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ABSTRACT

Cloud computing is a major pattern for large data storage and analytics. The combination of cloud computing and IoT can enable the resource sharing more efficiently than individually handling them. In distributed systems, the resources are termed as cloud services and handled in a centralized way. However, new challenges arise when integrating cloud for IoT. This paper presents the architecture for integrating of cloud computing for Internet of Things and its issues. Cloud computing has long been recognized as a paradigm for big data storage and analytics. The combination of cloud computing and IoT can enable ubiquitous sensing services and powerful processing of sensing data streams beyond the capability of individual "things", thus stimulating innovations 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, creating not only information from it, but also, knowledge and even wisdom. Internet of Things (IoT) becoming so pervasive that it is becoming important 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 utilization and storage capacity, but also, to make it possible to create more usefulness from the data generated by IoT's and develop smart applications for the users. For example, cloud platforms allow the sensing data to be stored and used intelligently for smart monitoring and actuation with the smart devices. Novel data fusion algorithms, machine learning methods, and artificial intelligence techniques can be implemented and run centralized or distributed on the cloud to achieve automated decision making. These will boost the development of new applications such as smart cities, grids, and transportation systems.

***Keywords*:** Cloud of Computing, Internet Things (IoT), big data, CoT

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1. INTRODUCTION

The next wave in the era of computing will be outside the realm of the traditional desktop. In the Internet of Things (IoT) paradigm, many of the objects that surround us will be on the network in one form or another. Radio Frequency IDentification (RFID) and sensor network technologies will rise to meet this new challenge, in which information and communication systems are invisibly embedded in the environment around us. This results in the generation of enormous amounts of data which have to be stored, processed and presented in a seamless, efficient, and easily interpretable form. This model will consist of services that are commodities and delivered in a manner similar to traditional commodities. Cloud computing can provide the virtual infrastructure for such utility computing which integrates monitoring devices, storage devices, analytics tools, visualization platforms and client delivery. The cost based model that Cloud computing offers will enable end-to-end service provisioning for businesses and users to access applications on demand from anywhere.

Smart connectivity with existing networks and context-aware computation using network resources is an indispensable part of IoT. With the growing presence of WiFi and 4G-LTE wireless Internet access, the evolution towards ubiquitous information and communication networks is already evident. However, for the Internet of Things vision to successfully emerge, the computing paradigm will need to go beyond traditional mobile computing scenarios that use smart phones and portables, and evolve into connecting everyday existing objects and embedding intelligence into our environment. 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 behavior. With these three fundamental grounds in place, smart connectivity and context-aware computation can be accomplished.

The term Internet of Things was first coined by Kevin Ashton in 1999 in the context of supply chain management. However, in the past decade, the definition has been more inclusive covering wide range of applications like healthcare, utilities, transport, etc. Although the definition of 'Things' has changed as technology evolved, the main goal of making a computer sense information without the aid of human intervention remains the same. A radical evolution of the current Internet into a Network of interconnected *objects* that not only harvests information from the environment (sensing) and interacts with the physical world (actuation/command/control), but also uses existing Internet standards to provide services for information transfer, analytics, applications, and communications.

Fueled by the prevalence of devices enabled by open wireless technology such as Bluetooth, radio frequency identification (RFID), Wi-Fi, and telephonic data services as well as embedded sensor and actuator nodes, IoT has stepped out of its infancy and is on the verge of transforming the current static Internet into a fully integrated Future Internet. The Internet revolution led to the interconnection between people at an unprecedented scale and pace.

The next revolution will be the interconnection between objects to create a smart environment. Only in 2011 did the number of interconnected devices on the planet overtake the actual number of people. Currently there are 9 billion interconnected devices and it is expected to reach 24 billion devices by 2020.

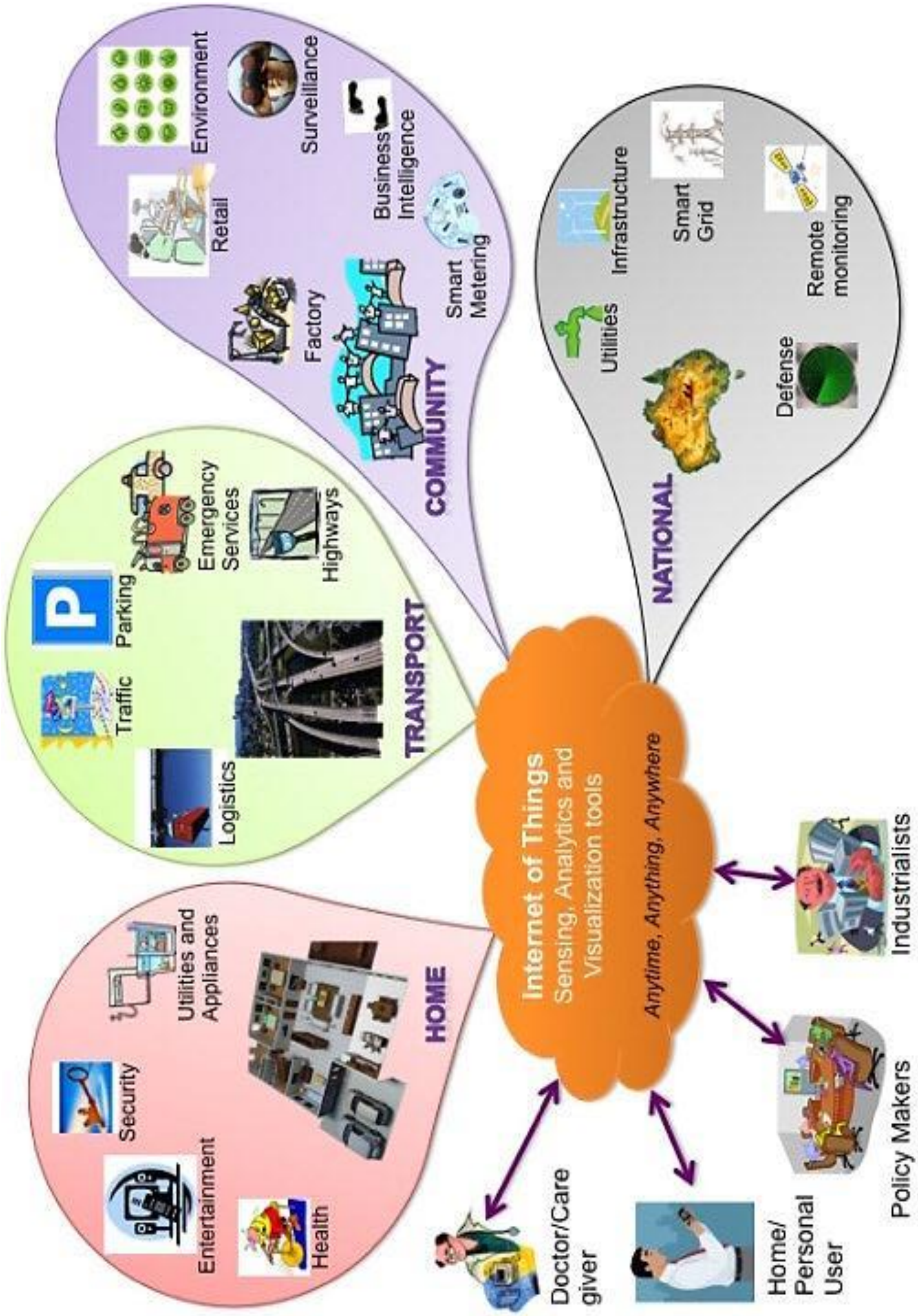

Figure 1. Internet of Things schematic showing the end users and application areas based on data.

According to the GSMA, this amounts to $1.3 trillion revenue opportunities for mobile network operators alone spanning vertical segments such as health, automotive, utilities and consumer electronics. A schematic of the interconnection of objects is depicted in Figure 1, where the application domains are chosen based on the scale of the impact of the data generated. The users span from individual to national level organizations addressing wide ranging issues.

2. CLOUD COMPUTING

Cloud computing is a model to share resources. Nowadays, cloud computing is also useful in IT, where the user do not need 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 provides the universal access to sensor data.
- **Platform as a Service (PaaS)**: The ability delivered to the consumer is to organize onto the cloud infrastructure consumer created or acquired applications created using programming languages, libraries, services, and tools supported by the provider.
- **Infrastructure as a Service (IaaS)**: The skill delivered to the customer is for processing, storage and other computing resources where the customer can organize and run arbitary software, which can include operating systems and applications.

However, developing IoT applications using low-level Cloud programming models and interfaces such as Thread and MapReduce models is complex (Figure 2). To overcome this, we need an IoT application specific framework for rapid creation of applications and their deployment on Cloud infrastructures. This is achieved by mapping the proposed framework to Cloud APIs offered by platforms such as Aneka. Therefore, the new IoT application specific framework should be able to provide support for:

- reading data streams either from senors directly or fetch the data from databases,
- easy expression of data analysis logic as functions/operators that process data streams in a transparent and scalable manner on Cloud infrastructures, and
- if any events of interest are detected, outcomes should be passed to output streams, which are connected to a visualization program.

Using such a framework, the developer of IoT applications will able to harness the power of Cloud computing without knowing low-level details of creating reliable and scale applications. A model for the realization of such an environment for IoT applications is shown in Figure 3, thus reducing the time and cost involved in engineering IoT applications.

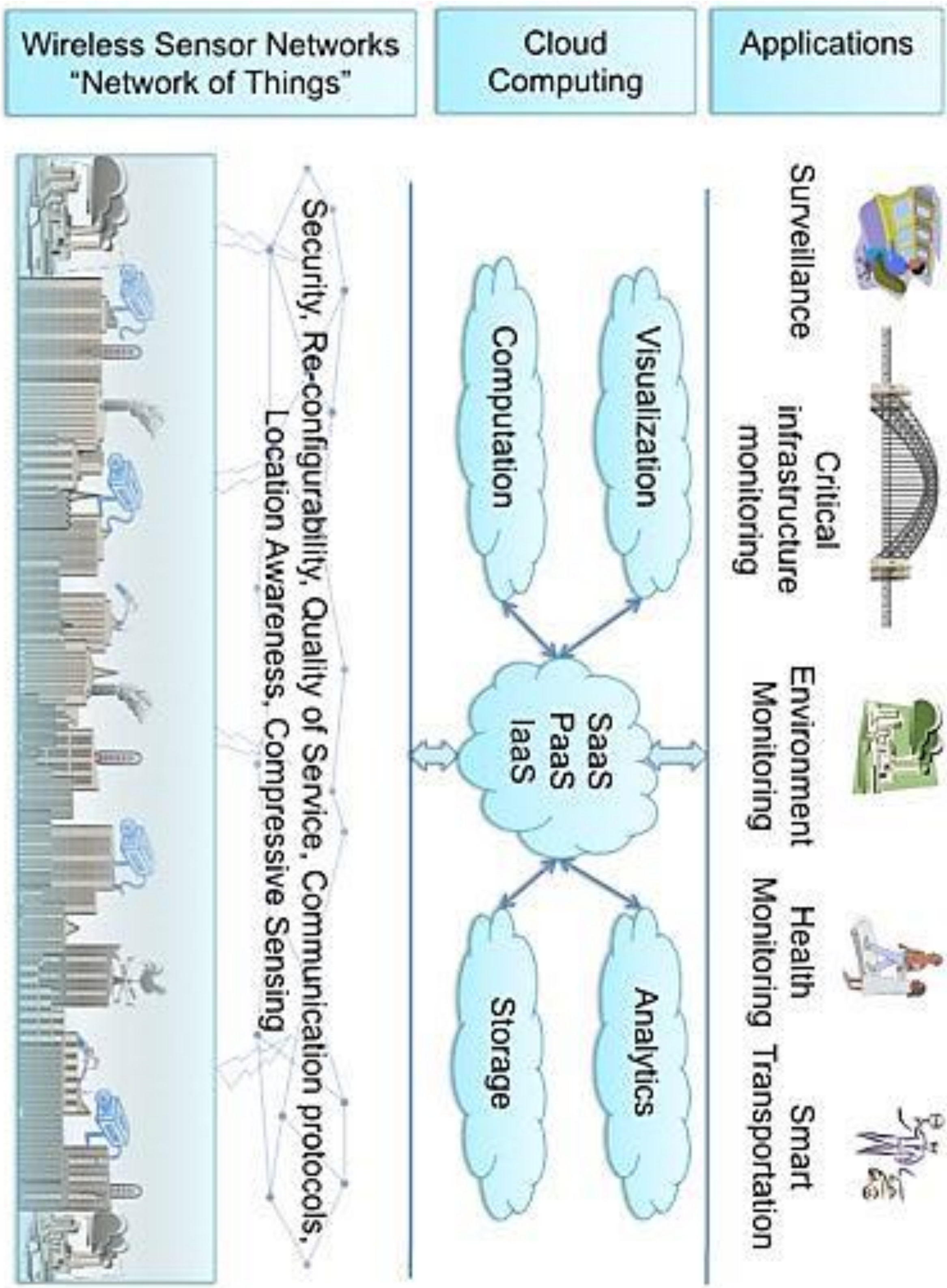

Figure 2. A figure containing the service models of cloud computing.

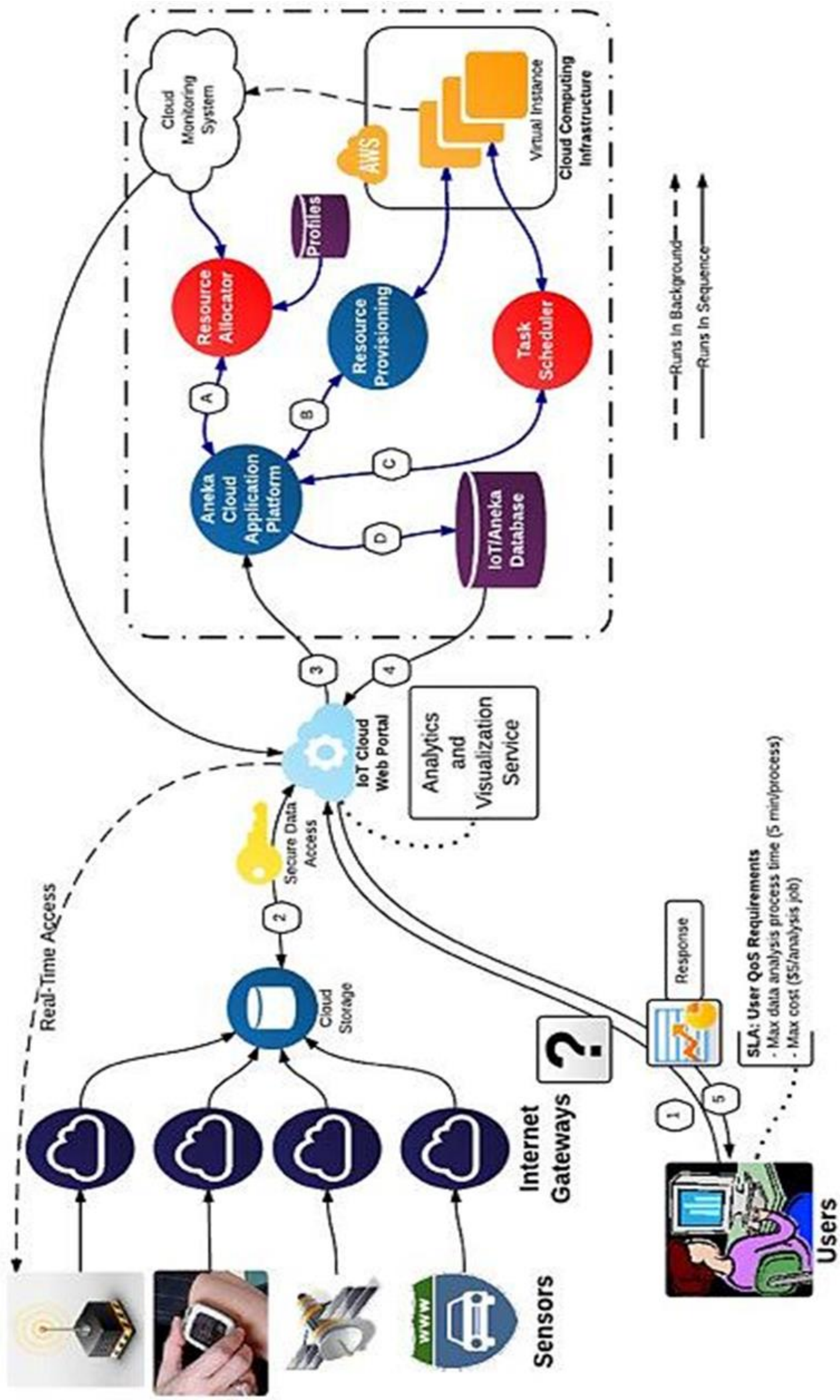

Figure 3. Cloud programming models and interfaces.

3. INTERNET OF THINGS

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

This will necessary result in the generation of the extent amount of data, which have to be stored, processed and accessed. For big data storage and analytics, a Cloud computing concept has been recognized. We can enable ubiquitous sensing services and powerful processing of sensing data streams beyond the capability of individual "things" by the combination of cloud computing and IoT. Thus, innovations are stimulating in both fields. For example, cloud platforms allow the sensing data to be stored and used intelligently for smart monitoring and actuation with the smart devices. To achieve automated decision making a cloud, novel data fusion algorithms, machine learning methods, and artificial intelligence techniques can be implemented and run as centralized or distributed.

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

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

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 be added.

This five-layer architecture is described in Figure 4.

- ✓ **Business layer:** Business layer is subjected to making money by processing the results or services received from application layer. For management of IoT system including the applications and services are responsible of the business layer. The success of IoT technology depends on good business models.
- ✓ **Application layer:** Application layer couples business services and provides services to the end user (Web Service, UI, etc.). The application layer bridges the gap between the business layer and the boundary technology.

- ✓ **Perception layer:** The perception layer can be abstracted as sensing components/nodes, actuator components/nodes. Sensing components include sensors, RFID, bar code label, intelligent detection instruments and meters, etc. Actuator Components include valve switch, relay, etc. Sensing components and actuator components realize signal acquisition and control functions. The collected information is forwarded to the Network layer for secure transmission.
- ✓ **Network layer:** Network layer includes various bus such as the controller area network (CAN) bus, the RS- 485 bus, etc., or wireless network such as wireless sensor network (WSN), Bluetooth, WiFi, etc. It realizes communication connection between perception components, or between perception components and IoT gateway (coordinator).
- ✓ **Middleware layer:** Middleware layer is between application layer and network layer and it receives the data from network layer and it takes decisions based on the performed results and forward that results to application layer. Data storage and managing services is the main activity of this layer. This layer is responsible for the service management and has link to the database.

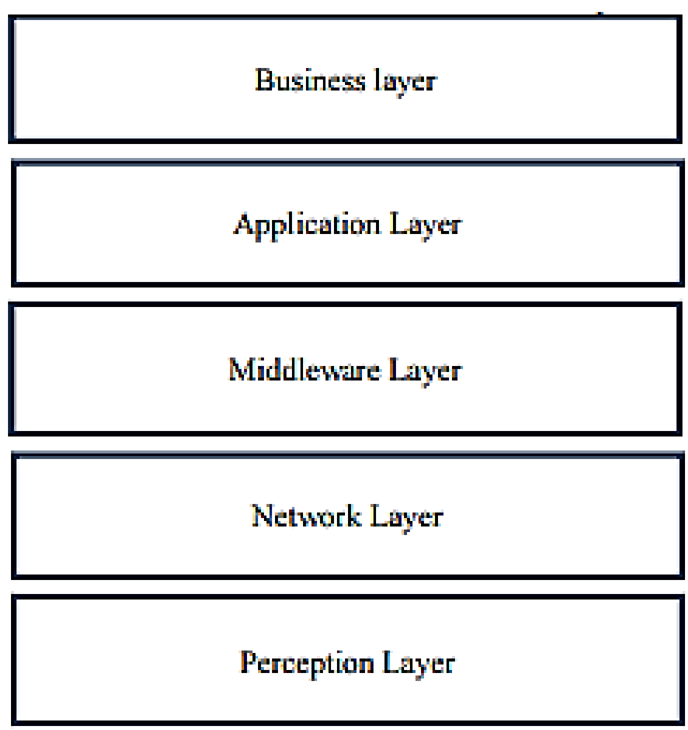

Figure 4. Layers of IoT.

4. INTEGRATION OF CLOUD COMPUTING AND INTERNET OF THINGS

All p IoT can benefit from the virtually unlimited capabilities and resources of Cloud to compensate its technological constraints (e.g., storage, processing and energy). Essentially, between the nodes and the applications, the Cloud acts as intermediate layer. Some of the issues can be solved, and the advantages can be obtained when adopting the CoT concept. As the number of connected devices increased, more data is required. To store huge amount of data, huge space and more processing is needed. More processing is not possible with IoT. More processing and computation are only possible with cloud computing. Cloud computing gives effective solution to implement IoT service management and composition. The cloud can provide actual solution to implement IoT service management and composition as well as applications that exploit the things or data formed by them. Also, the Cloud can benefit from IoT by spreading its opportunity to deal with real world things in a more distributed and lively manner, and for bringing new facilities in a large number of real life situations. Cloud computing and IoT working in integration make an orientation. How data is communicated between IoT and Cloud in integration is shown in Figure 5.

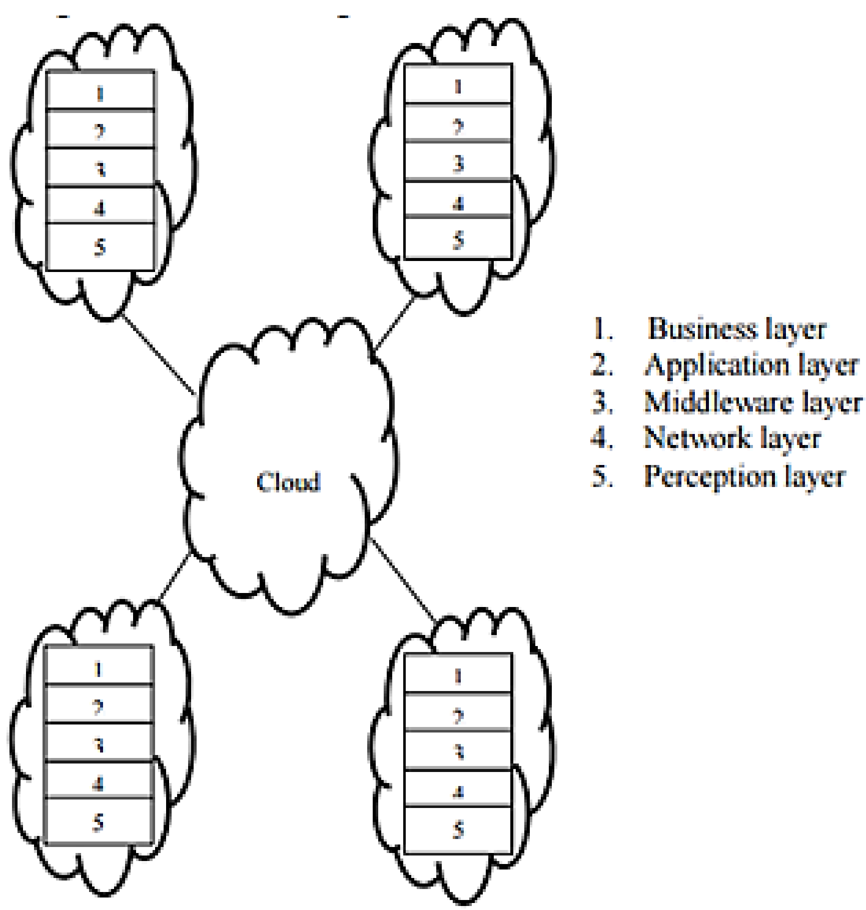

Figure 5. Data communication between cloud and IoT.

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

- **SaaS (Sensing as a Service),** providing ubiquitous access to sensor data
- **SAaaS (Sensing and Actuation as a Service),** enabling automatic control logics implemented in the Cloud

- **SEaaS (Sensor Event as a Service),** dispatching messaging services triggered by sensor events
- **SenaaS (Sensor as a Service),** enabling ubiquitous management of remote sensors
- **DBaaS (DataBase as a Service),** enabling ubiquitous database management
- **DaaS (Data as a Service),** providing ubiquitous access to any data
- **EaaS (Ethernet as a Service),** providing ubiquitous layer-2 connectivity to remote devices
- **IPMaaS (Identity and Policy Management as a Service),** enabling ubiquitous access to policy and identity management functionalities.
- **VSaaS (Video Surveillance as a Service),** providing ubiquitous access to recorded video and implementing complex analyzes in the Cloud.

5. PROTOCOLS USED IN CLOUD OF THINGS

✓ **CoAP (Constrained Application Protocol)**: In the Cloud of Things architecture, CoAP protocol is used to interact with Things. This protocol is similar to the HTTP protocol, and it provides request/response interaction model between the application end-points. Both CoAP HTTP protocols are based on same client/server model, and both are represented by same interaction model. The CoAP protocol exchanges the messages asynchronously over User Datagram Protocol (UDP), and to retrieve the resources from WSN nodes or telematics devices GET method is used. In order to modify the existing resource on a sensor nodes, or a telematics device PUT method is used. Using the Representational State Transfer (REST) methods of GET, PUT, DELETE, POST resources are requested and identified by the URIs. This protocol also provides a high level of communication security.

✓ **6LoWPAN (Low Power Wireless Area Networks)**: 6LoWPAN protocol is IPv6 based protocol. The innovation of 6LowPAN protocol is to provide IP access to awide set of networked devices, and it is of low-cost. Using cross-layer optimization approach, 6LoWPAN can reduce the IPv6/UDP header while maintaining the main functionalities and the size of the addressing space. This protocol is also supported for routing functionalities that are provided by the Routing Protocol for Low Power and Lossy Networks (RPL).

6. ISSUES OF CLOUD OF THINGS

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

- ✓ **Protocol Support** In homogeneous entities, different protocols must be used for different things to connect to the Internet, for example, consider a sensor IoT, which may be working on different protocols like WirelessHART, ZigBee, and 6LoWPAN. Here gateway device provides support for some protocols and for some protocols it might not have any support. Solutions can be given for this problem may be by mapping of standardized protocols in the gateway device.
- ✓ **Energy Efficiency** The main issue of cloud architecture is Energy Efficiency and this itself becomes an issue in Cloud of Things. Data communication between sensor networks and cloud consumes much power. A wireless is composed of four components such as sensing unit, processing unit, transceiver, and power unit. Power plays an important role in case of video sensing, video encoding, and decoding. Normally, as compared to decoding, video encoding is more difficult and reason for this is an efficient compression, the encoder has to analyse the redundancy in the video, and this is not suitable for low power entities such as batteries. For large number of sensors an efficient usage of energy and permanent power supply would be required.
- ✓ **Resource Allocation** Resource allocation is a very difficult challenge when different IoTs and unexpected things would be asking for resources on a cloud because it very difficult to decide what resources to be allocated for any particular IoTs. Resource allocation has to be mapped depending upon the sensor and the purpose for which sensor is being used, the type, amount, 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 identified with a unique identifier. It will be useful to communicate with objects that are in different network pool. The IPv6 address space is also support for this kind of ubiquitous networking.
- ✓ **Security Discovery** In Cloud of Things, the cloud manager has the responsibility to discover new services for the users and in IoT, any object can become part 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 become an issue in CoT. For managing the status of IoT nodes, track nodes, and keep the status updates of existing nodes, as well as newly added nodes of IoTs, an uniform way of service discovery approach is required.
- ✓ **Quality of Service** Provisioning The type and unpredictability come into play as the amount of data increases and also QoS (Quality of Service) becomes an issue. Depending upon the type of data and its urgency to be sent to the sync node, QoS must be supported.
- ✓ **Location of data storage** 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. Location also matters for critical and latency sensitive data. Nearest possible virtual storage server must be allocated for multimedia data.
- ✓ **Security and Privacy** Data security would be an issue on IoT side as well as on cloud side. In terms of privacy, sensitive or private data must be stored 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 necessary to upload the data to the cloud or sync device when anything would be able to connect to the Internet and to generate data.

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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.

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