Analysis of Internet of Things and Cloud Computing:Principles, Paradigms and Future

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Abstract—**concisely, the Internet of Things is the concept of connecting any number of devices (so long as it has an on/off switch) to the Internet and to other connected and interconnected devices. The IoT is a big network of connected things and human beings– all of which collect and share data about the way they are used and about the environment around them. This paper represents the principles, paradigms and security challenges of IoT.**

Keywords- Internet, Network, Security etc.

I. INTRODUCTION

Basically devices and objects with sensors are connected to an Internet of Things platform, which integrates the data from the various devices and applies analytical approach to share the most desirable information with applications built to address specific needs. These powerful IoT platforms can measure exactly what information is useful and what can be ignored that is not relevant. This information can be used to detect patterns, make recommendations, and detect possible problems before they occur and bring best possible outcomes Businesses can take advantage IoT applications to initiate safety tasks to performing the real-world testing using interconnected cameras and sensors by networks to detect how customers occupy with products. IoT has evolved from the convergence of wireless technologies, micro electromechanical systems (MEMS) and micro services and the internet. The concurrence has break down the barrier between the operational technologies and information technology, enabling unstructured machine produced data to be analyzed for insights to drive improvements. IoT evolved from machine-to-machine communication, i.e., machines connecting to each other via a network without human interaction. Machine to Machine refers to connecting a device to the cloud, managing it and collecting and maintaining data. Taking machine to machine to the next level, Internet of Things is a sensor network of billions of smart devices that connect people, systems and other applications to collect and share data.

II. IMPORTANCE OF IOT

1) How IoT works

An Internet of Thing ecosystem consists of web-enabled sensible devices that use processors, sensors and communication hardware to gather, send and act on infromation they acquire from their environments. IoT devices share the sensor information they collect by connecting to an IoT gateway or another edge device where data is either sent to the cloud to be analyzed. Sometimes, these devices communicate with different devices and act on the information they get from one another. The devices complete of the work without any human interfarence, although people can interact with the devices -- for instance, to set them up, give them instructions or access the data. The connectivity, communication and networking protocols used with these web-enabled devices mainly depend on the unique IoT applications deployed.

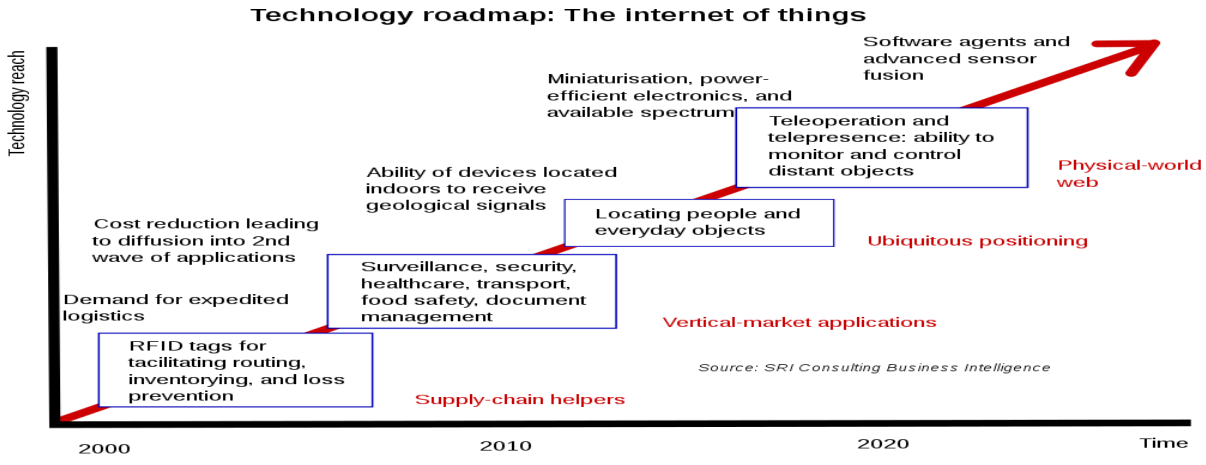
2) Why IoT is important

The term 'Internet of Things' was coined in 1999 by Kevin Ashton of Massachusetts Institute of technology (MIT).[1] In IOT, 'things' means any communicating or non-communicating object. Objects include physical entities like sensors, actuators, etc. The internet of things let people live and work smarter by gaining complete control over their lives. In addition to offering smart devices to automate homes, IoT is essential to business. Internet of Things provides businesses with a real-time interface into how their organisations systems work, delivering insights into everything from

the performance of machines to supply chain and logistics operations. IoT enables companies to automate the processes and bring down the labor costs. It also cuts down on waste and improves service delivery, and making it little expensive to manufacture and deliver goods as well as offering transparency into customer transactions. IoT alomost touches every industry, including healthcare, finance, retail and manufacturing, automobile. Smart cities help citizens reduce waste and energy consumption and connected sensors are even used in farming to help monitor crop and cattle yields and predict growth patterns. As such, IoT is one of the most important technologies of everyday life and it will continue to pick up steam as more businesses realize the potential of connected devices to keep them competitive.

III. VISION OF IOT

The vision of the Internet of Things (IoT) can be seen from two things — "Internet-centric" and "thing-centric." The Internet-centric architecture involves Internet services as the main focus, as data is being generated by the "things."IoT provides businesses with a real-time look into how their companies' systems really work, delivering insights into everything from the performance of machines to supply chain and logistics ope



rations.

IoT enables companies to automate processes and reduce labor costs. It also cuts down on waste and improves service delivery, making it less expensive to manufacture and deliver goods as well as offering transparency into customer transactions. IoT connected with every industry, including healthcare, finance, retail and manufacturing. Smart cities help citizens reduce waste and energy consumption and connected sensors are even used in farming to help monitor crop and cattle yields and predict growth patterns. As such, IoT is one of the most important technologies of everyday life and it will continue to pick up steam as more businesses realize the potential of connected devices to keep them competitive. RFID. In IoT scenario, a key role is played by Radio-Frequency Identification (RFID) systems, composed of one or more readers and several tags. These technologies help in automatic identification of anything they are attached to, and allow objects to be assigned unique digital identities, to be integrated into a network, and to be associated with digital information and services [2].

IV. CLOUD BASED ANALYSIS OF IOT

During 1970s, it was very popular for businesses to rent time using big, mainframe computer systems. These systems were extremely large and expensive too, so it didn't make sense financially for businesses to own the computing power themselves. Instead, they were owned by big corporations, government agencies, and universities. Microprocessor technology promised for remarkable reductions in size and expense, leading to the advent of the personal computer, which exploded in popularity in the 1980s. However, as high-speed connections have become widespread, the trend has been reversed: businesses are once again renting computing power from other organizations. Instead of buying expensive hardware for storage and processing in-house, it's easy to rent it for cheap in the cloud. The cloud is giant, interconnected network of powerful servers that performs services for businesses and for people.

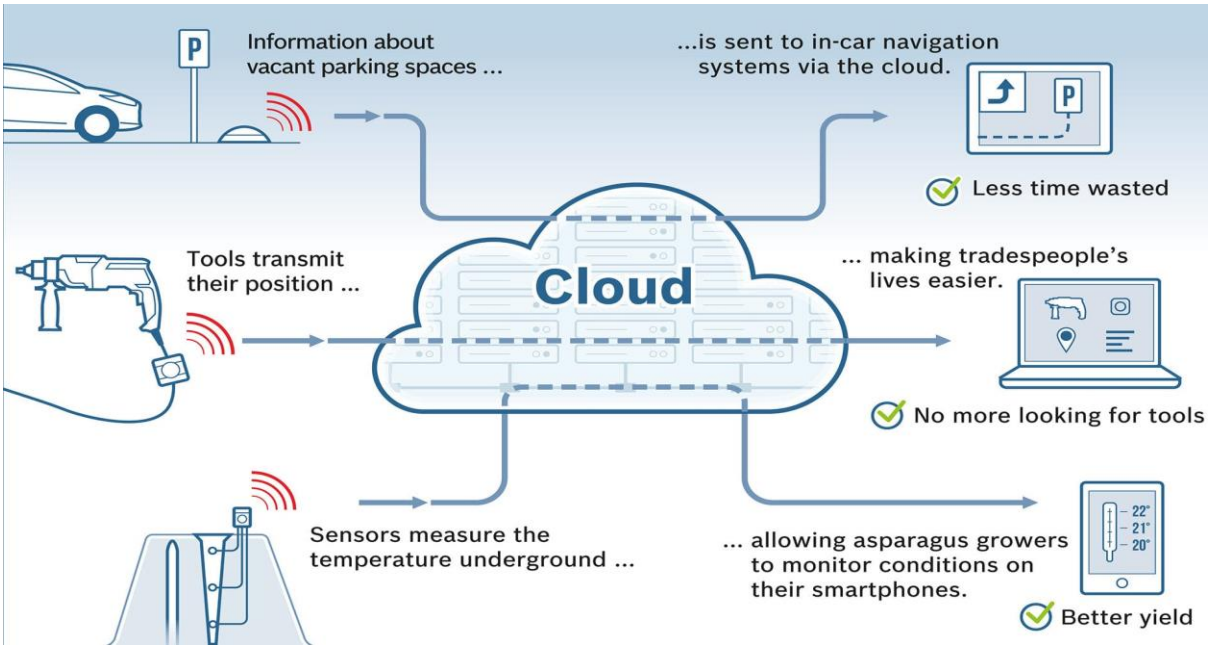


Image Source: https://www.devteam.space/blog/10-best-internet-of-things-iot-cloud-platforms/

The largest cloud providers are Amazon, Google, and Microsoft, who have big infrastructure of servers that they rent to businesses as part of their cloud services. Generally, what that happens "in The Cloud" is any activity that takes place over an internet connection instead of on the device itself. Many Internet of Things systems make use of large numbers of sensors to collect data and then make intelligent decisions. National Institute of Standard and Technology (NIST) defines cloud computing as "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable IT resources that could be rapidly provisioned and released with minimal managerial effort or service provider interaction" [3]. Using the cloud is important for aggregating data and drawing insights from that data. For instance, a smart agriculture company would be able to compare soil moisture sensors from Kansas and Colorado after planting the same seeds. With the absence of the cloud, comparing data across wider areas is much more difficult. Cloud computing is a step further of grid computing, parallel computing and distributed computing [4].

Using the cloud also allows for high scalability and data efficiency. When you have hundreds, thousands, or even millions of sensors, putting large amounts of computational power on each sensor will be extremely expensive and energy consuming. Instead of it, data can be passed to the cloud from all these sensors and processed there in aggregate form and desired data can be sorted out easily. For much of Internet of Things, the head of the system is in the cloud. The Sensors and devices collect data and perform necessary actions, but the processing/commanding/analytics , typically happens in the cloud.

Enter cloud computing- is an on-demand delivery of computational power, database storage, applications and information technological resources. It enables organizations to consume a compute resource, like a virtual machine (VM) instead of building a computing infrastructure on their premises. Today, cloud computing has more or less penetrated mainstreams IT and its infrastructure. Many technological giants such as Amazon, Alibaba, Google and Oracle are building machine learning tools with the help of cloud technology to offer a wide range of solutions to businesses worldwide.

How IoT and cloud complement each other

Cloud computing, as well as IoT, work towards increasing the efficiency of everyday tasks and both have a complementary relationship. On one side, Internet of Thing produces lots of data while on the other side, cloud computing paves way for this data to travel. There are many cloud providers who take advantage of this to provide a pay-as-you-use model where

customers pay for the desired resources used. Also, cloud hosting as a service adds value to Internet of Thing startups by providing economies of scale to reduce their overall cost structure.

In addition to this, cloud computing also authorizes to make better collaboration for developers, which is the order of the time in the Internet of Thing space. By facilitating the developers to collect and store as well as access data remotely, the cloud allows developers to implement projects without any delay. Also, by storing data in the cloud, Internet of Thing organizations can access a huge amount of Big Data. So, in a bid to lay down the relationship between IoT and cloud, here is a table (given below) that will let you know how they fit into each other like a glove. Cloud can fulfill direct interaction of the user to sensors/actuators (i.e. to support event-based systems) and can satisfy some specific requirements like internal network interconnection (i.e. any digital appliance in smart home should be able to interconnect with any other), intelligent remote control (i.e. equipments and services in the smart home should be intelligently manageable at any instant of time 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) [9]

PARAMETER	INTERNET OF THINGS	CLOUD COMPUTING
Big Data	IoT acts as a source	Manages Big Data
Storage	Limited Storage	Wide and Huge
Reachability	Limited Reachability	Wide Reachability
Internet's Role	Point of Convergence	Acts as a means of delivering services
Components	Runs of hardware	Virtual machines with imitate hardware
Computing Capabilities	Limited	Virtually Limited

IoT's role in harnessing mobility is immense. However, its prowess would be incomplete without security. Cloud has made IoT more secure with preventive, detective and corrective controls. It has enabled users with strong security measures by providing effective authentication and encryption protocols. In addition to this, managing and securing the identity of the users has been possible for IoT products with the help of biometrics. All of this is possible because of cloud's security.

The Internet of Things is not only a single technology but a concept in which many new objects are connected. For an instance the street lights that are networked together, objects with embedded sensors, image recognition capabilities, augmented reality, close field communication with decision in position, management of new resources and services and etc. These all have created many business opportunities and added the complexity of information technology in almost every field. Distribution, transportation, procurement, reverse logistics, service environment are all areas in which information and "objects" are connected to each other and produced new business processes or they have created a much more efficient and profitable inventory. The IoT provides aggregate IT-based solutions, which refers to the usage of hardware and software to store, retrieve, process data and technology communication including an electronic system for communication between individuals or groups. The rapid convergence of information technology and communication technology are taking place in three pillars of technological innovation [16].

V. INTEGRATION OF IOT AND CLOUD COMPUTING IN VARIOUS DISCIPLINES

Here we will discuss about the wide set of applications that are made possible with the help of CloudIoT Paradigms. The Internet of Things is starting to transform and revolutionize how we live our lives, but all of the added convenience and increased efficiency comes at a cost. The IoT is generating an unprecedented amount of data, which in turn puts a tremendous strain on the Internet infrastructure. As a result,organizations are working to find ways to alleviate that pressure and solve the data problem. Cloud computing will be a major part of that, especially by making all of the connected devices work all together. But there are some other specific differences between cloud computing and the IoT that will play out in the coming years as we generate more and more data. The blending of IoT resources into the Cloud introduces new resource

management requirements, which are associated with the need to optimize not only processing, storage and input output resources, but also sensor reading cycles, multi-sensor queries and shared access to expensive location-dependent IoT resources [6]. Several challenges should be enough addressed to realize the full potential of such application. Large scale distributed sources raise issues about discrepancy, data size and collection rate, latency dynamics, and cost of security enforcement [7]. The interference of multiple physical sensors in the scope of service delivery creates additional challenges associated with real-time interactions, which imposes a need for studying extensions over real-time operating systems for embedded devices, as well as how they could be supported in the scope of a Cloud environment [8]. CloudIoT involves several heterogeneous network technologies, where many applications require continuity in the transmission of data and overall consumption of bandwidth increases dramatically. On the one hand, the efficiency of the access management for enabling continuity and for optimizing the bandwidth usage is still an open issue [10]. Furthermore, being lack of mobility a typical aspect of common IoT devices, the mobility of sensors introduced by smart phones as well as wearable electronics represents a new challenge [11].

Difference between Cloud Computing and IoT

Cloud computing, simply called "the cloud," involves delivering data, applications, photos, videos, and more over the Internet to data collection centers. IBM has categorized cloud computing into six different categories:

- *Software as a service (SaaS):* Cloud-based applications run on computers off site (or "in the cloud"). Other persons or organizations own and operate these devices, which connect to users' computers, typically with the help of a web browser.
- *Platform as a service (PaaS):* Here, the cloud stores everything necessary to build and deliver cloud-based applications. This excludes the need to purchase and maintain hardware, software, hosting, and more.
- *Infrastructure as a service (IaaS)*: IaaS provides companies with servers, storage, networking, and data centers on a per-use basis for maintain the data.
- *Public Cloud*: Companies own and operate these spaces and provide quick access to the users over a reliable public network.
- *Private Cloud*: Similar to a public cloud, except only one thing (user, organization, company, etc.) has access.
- *Hybrid Cloud*: Takes the foundation of a private cloud but can provides public cloud access.

The Internet of Things refers to the connection of devices (other than the usual examples such as computers and smart phones) to the Internet. For an instance Cars, kitchen appliances, and even heart monitors can all be connected through the IoT. And as the Internet of Things surges in the coming years, more devices will join the list. The Internet of Things and cloud computing are different, but each will have their own nature of work in tackling this new world of data.

There are several aspects that apply to IoT systems that affect their architecture and implementation, as follows: • *Scalability*: Scale for IOT system applies in terms of the numbers of sensors and valuators are connected to the system, in terms of the networks which connect themselves together, in terms of the total amount of data related with the system and its speed of movement and also in terms of the amount of processing power required.

• *Big Data*: Many advanced IoT systems depend on the analysis of huge availability of data. There is a need, for example, to extract patterns from historical data that can be used to drive decisions about the future actions. The extraction of useful and desired information from complex data such as video is another example of analysis and requiring large amounts of processing. The ability to mine the existing data for new insights and the need to combine different datasets in novel ways are

characteristics likely to be part of an IoT system as well. Internet of Things systems are thus often classic examples of "Big Data" processing. As for privacy, providing properly designed authorization roles and policies while transparently guaranteeing that only authorized individuals have access to sensitive data is still a challenge, especially when data integrity must be ensured in response to authorized changes [12].

• *Cloud computing*: Internet of Thing systems frequently involve the use of cloud computing platforms. Cloud computing platforms provides the potential to use large amounts of resources, both in terms of the storage of data and also in the ability to bring flexible and scalable processing resources to the analysis of data. IoT systems are likely to require the use of a variety of data processing software – and the adaptability of cloud services is likely to be required in order to deal with new requirements based on maintaining the data, firmware or system updates and offer new capabilities over time.

• *Real time*: Internet of Thing systems often function in real time; data flows in continually about events in progress and there can be a need to produce timely responses to that stream of events and record of that events is maintained uniquely. This may involve stream processing; acting on the event data as it arrives, comparing it against previous events and also against static data in order to react in the most appropriate way. There is a parallel need to ensure that corrupted data is detected and not used – whether introduced by faulty sensors or malicious action – since the use of corrupted data could cause harm and damage to humans, equipment, and the environment.

• *Highly distributed*: IoT systems can compass whole buildings, measure whole cities, and even span the globe. Wide distribution can also apply to data – which can be stored at the edge of the network or stored centrally as per the requirements. Distribution can also apply to processing – some processing takes place centrally (in cloud services), but processing can take place at the edge of the network, either in the Internet of Thing gateways or even within (more capable types of) sensors and actuators. At present there are officially more mobile devices than people in the world. Mobile devices and networks are one of the best known IoT devices and networks.

• *Security and Privacy*: The question of the security and trustworthiness of distributed heterogeneous IoT systems is a big problem whose solutions must scale and evolve with the systems on its own. Data protection is necessary, including significant privacy concerns regarding data that relate to individuals and Gaining assurance that these systems are safe, secure, resilient and uphold their stakeholders expectations about privacy is especially challenging.

• *Compliance*: Providing confidence about the operation of these IoT systems is important both due to the regulations of specific industries, sectors and also the norms and expectations of the stakeholders of the IoT systems.

• *Integration*: IoT systems do not exist on their own, but need to connect to existing operational technology systems like factory systems, building control systems, and other types of physical management systems as well as existing enterprise systems including enterprise applications and enterprise databases [5].

Scalability and Flexibility: CloudIoT requires efficient mechanisms to match collected data and events to appropriate applications and services. Providing flexible subscription schemas and events management while guaranteeing scalability with respect to things and users is still considered an open issue [15].

VI. FUTURE AND CONCLUSION

A novel paradigm where Cloud and IoT are merged together is foreseen as disruptive and as an enabler of a large number of application scenarios [13]. A number of IT behemoths like Amazon Web Services already work on connecting the Cloud to the IoT ecosystem with others working on same kind of projects. This, among others, would enable content marketing and content distribution through a growing number of varied Internet of Things devices, which will result in new strategically approaches in the field of the Internet marketing practices. It is only a matter of time to see SaaS companies leveraging the power of the Cloud to deliver messages to connected IoT devices. We live in an age where somehow, somewhere, the cloud

seemingly processes every interaction, transaction, and communication. Almost every application in the world uses the cloud as its integration fabric. The information systems of future will become more focused on real-time experiences across an increasingly widening range of devices. Internet of Things, Artificial Intelligence, and hybrid cloud are three sides to the same triangle, three legs to the same stool—the holy trinity of IT. Together, these forces have elevated data as the core of modern-day application innovations. The future for this world of applications is unlimited. Hybrid cloud is not just a platform. It is built of strategy, as a leading technology solution, as an architectural marvel, and most importantly, as a promise to build into the future. The integration of Cloud Computing and Internet of Things represents the next big leap ahead in the Future Internet. The new applications arising from this integration – we called CloudIoT– open up new exciting directions for business and research [14].

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