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Analysis of Demand, Architecture and Challenges of the Internet of Things

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Abstract: The Internet of things involves sensor-configured devices, processing units, and various technologies to connect and exchange data between devices. IoT involves many tools and technologies that can provide the facility to interact with each other. The IoT with such advanced devices, tools and technologies help the advancement of current society. This paper includes the basic concepts of IoT, market demand analysis, four foundational pillars of IoT, and the architecture of IoT.

Keywords: Internet of Things, IoT, IoT Architecture, IoT Demand, IoT Requirement.

I. INTRODUCTION TO IoT

The IoT means a network with physical objects considered as "things" like sensors and actuators for interconnection, and data exchange with each other over the internet to make the system easier. At first Carnegie Mellon University (1882) discussed developing an Internet-connected "Coca-Cola Vending Machine" to report the inventory and temperature status of drinks. In 1999 Mr Kevin Ashton, P&G said about the term "Internet of Things" at MIT's Auto-ID Center, the concept was IoT using radio-frequency identification (RFID) to allow computers to manage all individual things. For intercommunication purposes, IoT devices generally refer to wireless connections with each other as many IoT systems involve smart sensor networks, which are mainly connected by a wireless communication medium. Wireless communication for devices, sensors, or anyone other is generally known as a Wireless Sensor Network (WSN) [1-3].

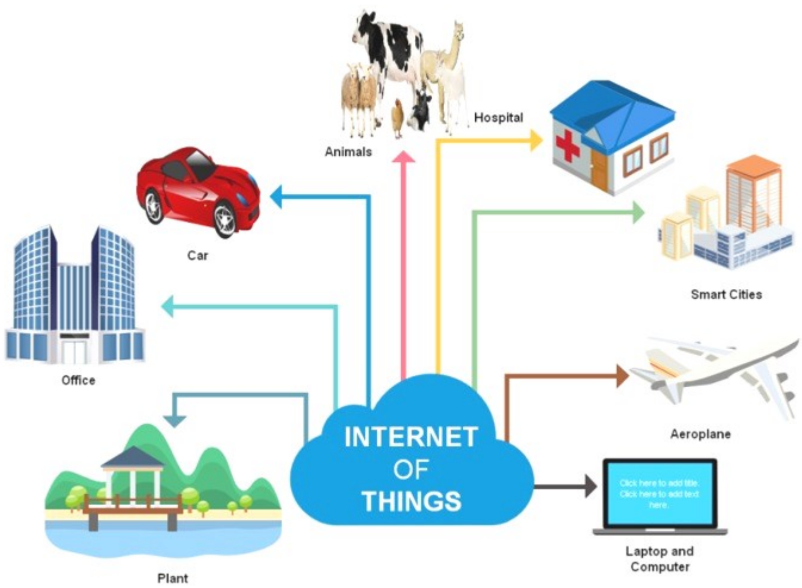

Figure 1: Application Areas of IoT

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The IoT ecosystem involves sensors for automation. A sensor is a physical device that can sense the appearance of various environmental or biological factors, so that as per detected input the system may react. The sensor is an electronic device; hence, the sensor's output is in the electric form. Based on the various environmental and biological conditions, various sensors have been designed. The sensor input helps devices to react which makes IoT capable of smarter decisions. The sensor has been designed to capture various conditions such as visual, infrared, seismic, magnetic, thermal, acoustic, radar, measurements, temperature, pressure, humidity; vibration, radiation, noise level, motion, soil erosion, speed, direction, and size. The sensors have been also designed for continuous sensing, event detection, location sensing, and local control. [4]

Various tools and technologies have been designed to make IoT devices capable of wireless interaction. The IoT with such advanced tools, technologies and devices makes human work easy and perfect. In the current era, IoT devices becoming more useful and popular. Due to the IoT era, sensors are everywhere in society and in future, the trend will increase again. The IoT used various sensors to sense the various environmental or biological factors as per the requirement, it may be available at geographically dispersed locations, so wireless communication is preferable.

In the industry 4.0 era, most of the industrial equipment and machinery including various sensors. Most equipment and machines follow the Robotic Process Automation approach (RPA) through advanced technologies such as artificial intelligence (AI), machine learning (ML), cloud computing (CC), etc. [1]. As IoT use and demand increase, various challenges occur hence to provide the solution research needs have arisen. As per the analysis, low-powered wireless devices with high data security are the most viable demand for IoT applications. A standard IoT architecture includes hardware, communication medium, software system and application layer. [5]

The communication layer is a critical bridge between all the other layers and consists of a multi-layer stack, including the data link, network or transport, and session protocols. Bluetooth is at the data link layer to establish a sensor-to-sensor connection or sensor-to-gateway connection.

For wirelessly data sharing, nowadays various technologies have been designed such as RFID, Infrared, Near-Field Communication (NFC), Bluetooth, Li-Fi, Wi-Fi, Zigbee, LoRa etc. The present most communication technologies have wireless channels that have high rates of distortion and are unreliable, therefore reliable data communication without too many retransmissions is an important issue. [6]

IoT applications include many sensors as per the requirement, as per the analysis, it is concluded that the present most sensors have limited sensing, computation, and communication capabilities. IoT with such sensors nullifies the aim of perfection, hence for IoT with such resource-constrained sensors, protocols with minimum payload but capable to broadcast sensors' limited data are required. The lightweight data improves the life of the sensor nodes and the bandwidth utilization of a network. [7]

The day-to-day nature of IoT applications becoming more complex as it includes the number of devices or sensor nodes. In the network, devices and sensor nodes regularly perform an interaction with each other, which generates a heavy dataset. To perform effective data transmission in the IoT network, well-tuned short-range communication technology is needed. The communication layer works as a bridge between all the other layers and consists of a multi-layer stack with a data link, network/transport, and session protocols. [7-10]

II. DEMAND FOR IoT

IoT is more than just the latest buzzword about the future of business and technology. IoT is transforming everyday business practices and opening new windows of opportunity. The use of IoT is increasing day by day, in 2016 IHS Markit (The Technology Group at IHS Markit is the leading source of information, insight and analytics in critical areas that shape today's technology ecosystem from materials and components to devices and equipment, to end markets and consumers. [11]

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Businesses and governments in more than 150 countries around the globe rely on the deep market insight and expert independent analysis of 300+ industry analysts in technology sectors spanning IT, telecom, media, industrial, automotive, electronics, solar and more.) forecasted that IoT use has improved in the last decade, as the number of connected IoT devices worldwide will jump 12% on average annually, from nearly 27 billion in 2017 to 125 billion in 2030. Global data transmissions are expected to increase from 20-25% annually to 50% per year, on average, in the next 15 years [11].

The Five Essential IoT Requirements and How to Achieve Them-

2019, a white paper published by Cognizant Digital Business in 2019 analyzed that organizations which are usi ng IoT have decreased the supply chain costs (SCC) by approximately 20%, increased productivity by approxim ately 10% to 20% and decreased the production time approximately 20% to 50%. The use of IoT benefits the i ndustry lot but still many industries are reluctant to adopt the IoT, even though they face trouble in identifyin g a consistent IoT strategy. The IoT is a concept as IoT is a movement, not a market. IoT is a process, not a pro duct. IoT experiencing constantly evolving movement of change in process of human interaction with machin es. The IoT virtually impacts all stages of industry and society, it changes the process for the transformation of raw materials into the product, process distribution from manufactural to consumer, etc.

1. Medical reported 337 million IoT devices with the expectation for a growth of 20.8% compound annual g rowth rate (CAGR) during 2013-30.
2. Commercial & Industrial Electronics reported 4.3 billion IoT devices with the expectation for a growth of 20.3% CAGR during 2013-30.
3. Automotive & Transportation recorded 789 million IoT devices with the expectation for a growth of 21.4 % CAGR during 2013-30.
4. Consumers recorded 5.2 billion IoT devices with the expectation for a growth of 13.8% during 2013-30.
5. Communications recorded 14.6 billion IoT devices with the expectation for a growth of 7.8% CAGR durin g 2013-30.
6. Computer recorded 1.7 billion IoT devices with the expectation for a growth of -2% CAGR during 2013-30.

III. FOUR FOUNDATION PILLARS OF IoT

IHS Markit has identified four foundational, interconnected pillars at the core of the IoT movement: Connect, Collect, Compute, and Create. The entire IoT is built upon these four innovational pillars.

1. New Connections of devices and information.
2. Enhanced Collection of data from the connections of devices and information.
3. Advanced Computation that transforms collected data into new possibilities.
4. Unique Creation of new interactions, business models, and solutions.

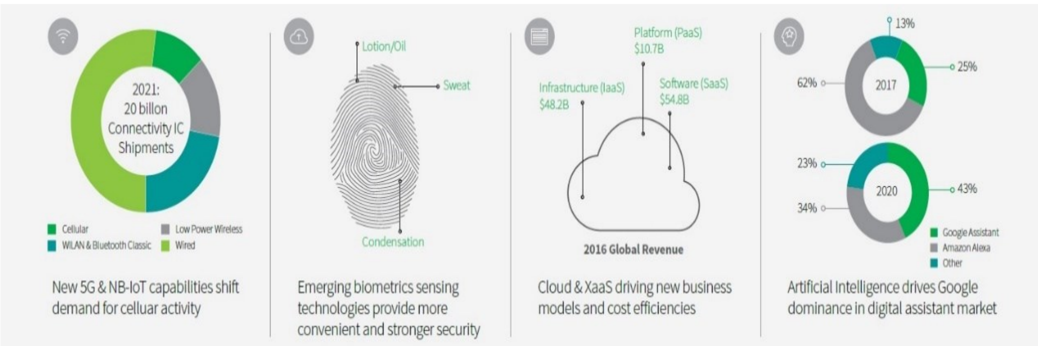

Figure 2: Application Areas of IoT

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IV. ARCHITECTURE OF IoT

There is no single universally accepted standard architecture for IoT. Different researchers proposed different architectures. A general IoT architecture includes hardware, software, communication medium and application layer. [12-14]

4.1) Three-Layer Architectures

It is the most basic architecture, introduced in the early stages as shown in Figure 3. It has three layers as follows:

i) Perception layer: It is the physical layer, which has sensors to sense and collect some physical parameters or identify other smart objects in the environment.

ii) Network layer: It allows the connections to other network colleague devices and servers. Its features are also used for transmitting and processing sensor data.

iii) Application layer: It provides delivering application-specific services to the user. It defines various applications in which the IoT can be deployed, for example, smart homes, smart cities, and smart health.

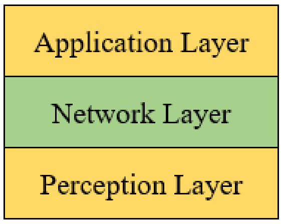

Figure 3: Three-Layer Architecture of a Smart IoT

4.2) Five-Layer Architectures

The three-layer architecture represented the basic IoT architecture, hence it is not sufficient for research on IoT as research must focus on specific aspects of the IoT. Hence, we have analyzed other architectures proposed in the literature. The three-layer architecture with adding two more layers is introduced as five-layer architecture. The role of the perception layer and application layer is the same as the three layers of architecture.
We defined the function for the remaining layers.

i) Transport layer: It transfers the data from the perception to the processing layer and vice versa through wireless networks like NFC, RFID, Bluetooth, LAN, and 3G.

ii) Processing layer (Middleware layer): It stores, analyzes and processes huge amounts of data that comes from the transport layer. It can manage and provide a diverse set of services to the lower layers. It includes many technologies such as databases, cloud computing, and big data processing modules.

iii) Business layer: It manages the total IoT system, including applications, business and profit models, and users' privacy.

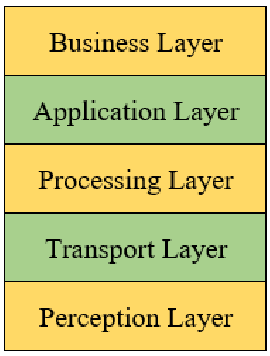

Figure 4: Five Layer Architecture of a Smart IoT

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4.3) Cloud-Based Architectures

We have not been clear about the nature of data generated by devices and the nature of data processing. In some system architectures, the data processing is done in a large centralized fashion by cloud computers. Such a cloud-centric architecture keeps the cloud at the centre, applications above it, and the network of smart things below it. Cloud computing provides great flexibility and scalability, giving priority to it. It offers services such as the core infrastructure, platform, software, and storage. Developers can provide their storage tools, software tools, data mining, machine learning tools, and visualization tools through the cloud.

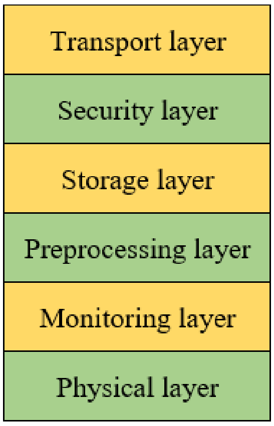

Figure 5: Cloud and Fog-Based Architecture of a Smart IoT

4.4) Fog-Based Architectures

In fog computing, the sensors and network gateways do a part of the data processing and analytics. Fog architecture presents a layered approach as shown in Figure 5, which inserts monitoring, preprocessing, storage, and security layers between the physical and transport layers. The monitoring layer monitors power, resources, responses, and services. The preprocessing layer performs filtering, processing, and analytics of sensor data. The temporary storage layer provides storage functionalities such as data replication, distribution, and storage. Finally, the security layer performs encryption/decryption and ensures data integrity and privacy.

Monitoring and preprocessing are done on the edge of the network before sending data to the cloud. Often the terms “fog computing” and “edge computing” are used interchangeably. The latter term predates the former and is construed to be more generic. Fog computing originally termed by Cisco refers to smart gateways and smart sensors, whereas edge computing is slightly more penetrative.

This paradigm envisions adding smart data preprocessing capabilities to physical devices such as motors, pumps, or lights. The aim is to do as much preprocessing of data as possible in these devices, which are termed to be at the edge of the network. In terms of the system architecture, the architectural diagram is not appreciably different from Figure 4. As a result, we do not describe edge computing separately.

4.5) Social IoT

In social IoT (SIoT), we consider social relationships between objects the same way humans form social relationships. Here are the three main facets of a SIoT system:

i) The SIoT is navigable. We can start with one device and navigate through all the devices that are connected to it. It is easy to discover new devices and services using such a social network of IoT devices.

ii) A need for trustworthiness (strength of the relationship) is present between devices.

iii) We can use models like studying human social networks to also study the social networks of IoT devices.

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V. CONCLUSION

The IoT involves sensor-configured devices, processing ability, and technologies to connect and exchange data between devices over the Internet or other communications networks. IoT systems have many tools and technologies to provide facilities to devices for interacting with each other. The IoT with such advanced devices, tools and technologies help the advancement of current society. This paper includes the basic concepts of IoT, market demand analysis, four foundational pillars of IoT, and the architecture of IoT. The analysis concluded that IoT systems are very useful in the industry 4.0 era, they are the future of the technological world.

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