A Review of Internet of Things: Qualifying Technologies and Boundless Horizon

[1*]Shalini Sharma Goel,[2]Anubhav Goel, [3]Mohit Kumar, [4]Germán Moltó

[1*] Computer science and engineering department, MIET Meerut, Meerut, India
[2]Polymer and Process Engineering Department, IIT Roorkee, Roorkee, India
[3]Information & Technology department, NIT Jalandhar, Jalandhar, India
[4]Instituto de Instrumentación para Imagen Molecular (I3M), Centro Mixto CSIC-Universitat Politècnica de València, Valencia, Spain

* E-mail:shalinis1508@gmail.com,agoel@pe.iitr.ac.in, kumarmohit@nitj.ac.in, gmolto@dsic.upv.es

Abstract: Internet of Things (IoT) is a new buzzword in information technology where real-world physical objects are made smart by integrating them with the internet enabled technologies. The things can sense information around them, communicate the sensed information over some protocol and employ the information to solve real life problems. In IoT several technologies are integrated under a common umbrella so that they can connect and exchange data over a network protocol. A huge amount of data is generated from diverse geographical locations with the consequent urge for fast aggregation of overall sensed information, leading an increase in need to store and process such data in more efficient and effective manner. The traditional fields of embedded systems, WSN, real time analytics, automation system, machine learning and others all contribute to enable the IoT. This article is focused in discussing the various IoT technologies, protocols and their application and usage in our daily life. It also summarizes the current state of art IoT architecture in various spheres conventionally and all related terminologies that will give the forthcoming researchers a glimpse of IoT as a whole.

Keywords- 6LoWPAN, 802.15.4, Actuators, AMQP, Bluetooth LE, Cloud, CoAP, Fog, IIoT, M2M, MQTT, RFID, SDN, VANET, WSN, Zwave, ZigBee,

1. INTRODUCTION

IoT is reshaping and revolutionizing every sphere from business to life. Boundless imaginations and infinite opportunities are promised by IoT. A myriad of devices will be wired up or connected wirelessly which means that vigorous information will be available at our fingertips. The vision of Internet of Things, which blends the actuation and sensing functions seamlessly in the background is escalated with actuating and communicating getting closer. Access of rich information sources has made new capabilities possible. All worldly goods around us will be equipped with embedded system. Till now approximately 9 billion devices are connected to the Internet and it is anticipated that this figure will rise to 20-50 billion by 2019. In the coming future, it is estimated that humans will be outnumbered as traffic generators or receivers; instead, traffic will majorly move between devices and other things connected via the Internet. The various technologies such as cloud computing, big data, Software-Defined Networking (SDN), Cyber Physical System (CPS), deep learning, networking, participatory sensing, GIS based visualisation, data mining, etc. will be unified soon.

IoT can be construed to be built in two different ways i.e. either expand the existing internet infrastructure or building separate internetwork of these physical devices from scratch **[1]**. Each approach has its own separate challenges. IoT can be categorized into Industrial IoT (IIoT) which is commonly known as enterprise IoT where IoT devices connect to an IP network and global network and an extensive M2M communication is foreseen and, second, is consumer IoT where IoT devices communicate with local area networks via technologies such as ZigBee, Bluetooth or Wi-Fi and there is a limited M2M communication **[2]**. Up till now the current IoT market share in healthcare is 30.3%, manufacturing business is 40.2%, in, 8.3% in retail, and 7.7% in security (surveillance and safety) **[1]**. Modern day IoT implementations incorporate smart parking, smart grids, tank levels, smart phone detection, traffic congestion, smart roads, radiation levels, landslide and avalanche prevention, smart product management, snow level monitoring and others. The heterogeneous service offering technologies are ZigBee, RFID, Wi-fi, Bluetooth, etc. The local connectivity is taken care by gateways and the global connectivity is offered by the Internet. LANs are interconnected via gateway nodes. The nodes within the gateway sovereignty have addresses that are valid within the gateway domain only. The same address may be repeated in another gateway's domain. This policy saves a lot of address wastage. Most IoT based solutions still use IPv4 but if we want to approach building IoT by expanding the existing internet then different addressing schemes needs to be followed i.e. address translation between IPv4 and IPv6 until a new addressing scheme is framed. IPv6 is preferred over IPv4 because of its large address space as compared to IPv4 i.e. 2^{128}.

In recent past, extensive research efforts have been made towards the development of IoT prototypes and evaluating the various aspects of IoT technologies. Few of the important studies are quoted hereafter. The survey work done by Al-Fuqaha et al. **[3]** presented the possible application areas of IoT, standard protocols used in diverse enabling technologies of IoT. IoT key challenges were also put forward to light up the future directions. Andrea et al. **[4]** unveiled disparate challenges in IoT and security frangibility and privacy issues from the physical system, network, software and application point of view. Atzori et al. **[5]** explained different visions of IoT and various enabling communication technologies. Convergence of cloud and IoT was mentioned in a very efficient manner in the work by Botta et al. [**6]**. An unconventional IoT infrastructure named Winternet was proposed by Wu and Zhao

[7], which can be designed and perceived by contemporaneous internet technologies. Lin et al. [**8]** mainly elaborates the assimilation of fog/edge computing with IoT. A new architecture of IoT comprising 5-layers was propounded by Wu et al. **[9]**.

In this paper, discussion about various IoT technologies, protocols and their application and usage in each day existence is presented. It also summarizes the modern state of art IoT architecture in numerous fields and all related terminologies. This is an effort to give the researchers a glimpse of IoT as a whole.

2. IoT SKELETON

IoT supports controlling objects and remote sensing across the whole network. Thus, sensors and actuators are its basic building block. A sensor is an electronic device whose purpose is to detect or measure changes in the process variable and send the information to other electronic circuits. Sensors can be classified as analog and digital based on their outputs and scalar and vector based on their data type. Various sensors exist in market to measure temperature, light, pressure, force, position, speed, sound, etc. The sensitivity of a sensor under real conditions may vary from the value specified and this is termed as sensitivity error. An actuator can be seen as device responsible for controlling a process or system and, thus, it requires a signal from a control system and an energy source to operate. It converts the signal received by the controller into a mechanical motion acting upon the practical setup. There exist various actuator types i.e. hydraulic, pneumatic, electrical, thermal, mechanical, soft, light activated polymer (LAP) etc. The underlying IoT service-oriented architecture has 4 basic layers **[10]**.

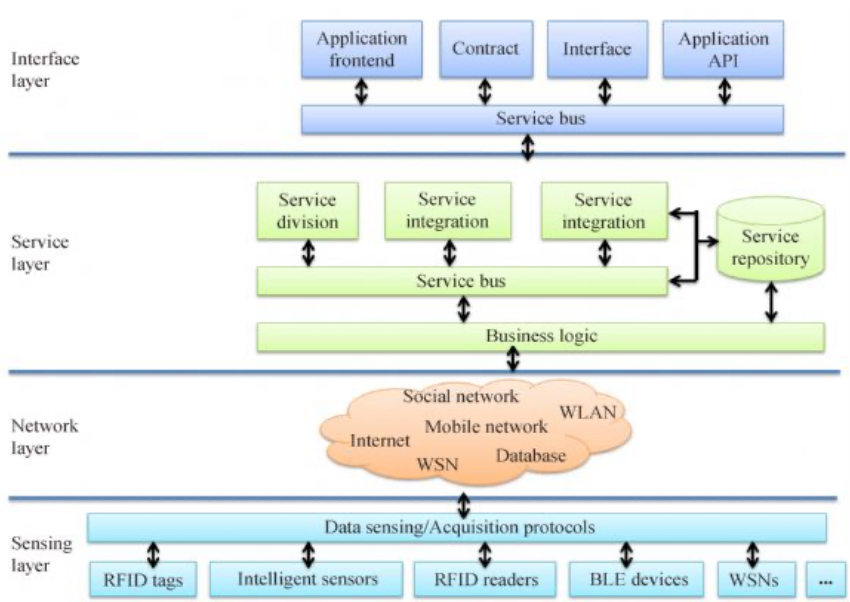

Fig 1: IoT Service Oriented Architecture

The disparate data protocols which forms the basis of IoT protocol organization are MQTT, CoAP, AMQP. Message queue telemetry transport (MQTT), which is designed to provide connectivity between application and middlewares on one side and network and communication on the other side, is a publish subscribe lightweight messaging protocol used in conjunction with TCP/IP. It is primarily designed for remote connections with limited bandwidth and it features a small code footprint. It has three components: publishers, subscribers, broker. Constrained Application Protocol (CoAP) is a web transfer protocol, basically a session layer protocol, which builds over UDP and is designed for machine to machine (M2M) communication **[11]**. Advanced Message Queuing protocol (AMQP) is a binary application layer protocol used to connect business and system process. *At most once*, *at least once* and *exactly once* are the types of message delivery guarantees offered by AMQP. It enables offline clients to fetch data later which introduces fully asynchronous functionality for systems.

2.1 Connecting Technologies

IEEE 802.15.4 is a well-known standard for low data rate WPAN (Wireless Personal Area Network) focussed on low cost, low speed pervasive communication among devices. It uses the physical and MAC layer to communicate with all upper layers. The standard transmission range of IEEE 802.15.4 is 10m to 75m and uses CSMA/CA for channel access to resolve contentions. It uses Direct Sequence Spread Spectrum (DSSS). The networking topologies elucidated are star and mesh. The standard specifies two types of network nodes i.e. Full Function Device (FFD) which can communicate to all types of devices and Reduced Function Device (RFD) which can interact to only FFD **[12]**.

ZigBee protocol is defined by the layer 3 of the OSI model and works with the IEEE 802.15.4 standard. The most preferred use of ZigBee is wireless sensor networks (WSN) using the mesh topology. ZigBee is used in home automation, telecom services, medical device data collection, etc. Wireless Highway Addressable Remote Transducer (HART) is a sensor networking technology developed for Network Smart Field Devices that enables a cheaper and more approachable placement of devices. It operates on the 2.4 GHz ISM band **[13]**. IPv6 Low Power Wireless Personal Area Network (6LoWPAN) allows the minor devices to impart information wirelessly. It allows low power gadgets to connect to the Internet. Its basic uses are inculcated in the areas of smart grids, M2M, etc. The routing protocols used by 6LoWPAN are Lightweight On Demand Ad hoc Distance vector routing protocol (LOADng) procured from Adhoc On Demand Vector routing protocol (AODV) and Routing over low power lossy networks (RPL) gleaned from Destination Sequenced Distance Vector routing (DSDV) **[14]**.

Radio Frequency Identification (RFID) tags consist of integrated circuits, smart labels, RFID readers and antennas used in variegated sectors as inventory management, ID badging, Supply Chain Management, Asset Tracking, etc. Bluetooth Low Energy which is a short-range communication technology is a Wireless Personal Area Network (WPAN) technology. It can range up to 100 m based on ad hoc technology. The devices connecting via Bluetooth can be in any one of the states i.e. sniff, hold, active and park. When two or more Bluetooth devices communicate, it forms a piconet. Piconets can form a physically extensible communication infrastructure called scatternets.

Z-wave is a home automation technology used for transmission of information among devices. It avails a mesh topology and utilizes Gaussian Frequency Shift Keying (GFSK) and Manchester channel encoding. When the devices are out of range, the messages forwarded by a gadget are routed through different nodes to bypass hindrances fabricated by household apparatus and this process is called healing **[15]**. The International Society of Automation (ISA) 100.11a standard is used for large scale industrial complexes. It is flexible, reliable and supports multiple protocols for numerous applications.

2.2 Wireless Sensor Network

Wireless Sensor Networks (WSN) are spatially distributed and battery powered, self-governing sensors having short transmission range deployed densely over an area which can measure the surrounding environment. A WSN typically has little or no infrastructure. The basic components of sensor node are:

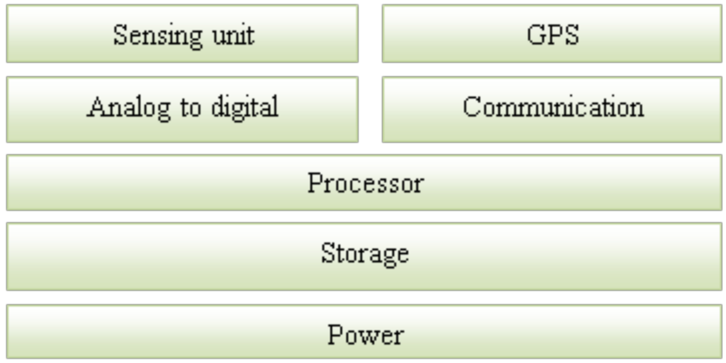

Fig 2: Components of a sensor node

Two basic types of WSN exist: structured and unstructured **[16]**. In WSN, nodes are prone to malicious attacks as it is open medium. The node behaviour in WSN may vary according to environmental conditions. The several applications of WSN includes healthcare, mines, object tracking, agriculture, etc. The sensors are deployed in such a way that they all are connected and cover the area of interest satisfactorily. The main aim is that the sensed information reaches the sink node through intermediate relay nodes. Optimal Geographical Density Control (OGDC) is the protocol conceived in WSN that strives to combine coverage and connectivity in which the nodes can be in one of the three states: on, off and undecided **[17]**. If transmission range ≥ 2* sensing range i.e. $R_c \geq 2R_s$ then it is evident that coverage implies connectivity. A continuous area R is covered by sensors if every crossing that exist in R is covered**[18]**. The types of sensor network established so far are terrestrial, aerial, underground, underwater, multimedia and mobile WSN.

3. A PARADIGM SHIFT: SOFTWARE DEFINED NETWORKING

The outbreak of mobile devices and subject matter, materialization of cloud services, server virtualization are among the recent drifts propelling the networking industry to reassess conventional network architectures. Almost all established networks are stratified, lack centralized control, are built with layers of Ethernet switches organized in a tree structure. This design is comprehended when client-server computing was superior, but now in the IoT era, such a consistent architecture is not well suited to the transformed computing and storage needs of today's industry setup. Legacy networks have become difficult to automate **[19]**. The traditional architecture follows a vendor specific architecture which limits the dynamic configuration.

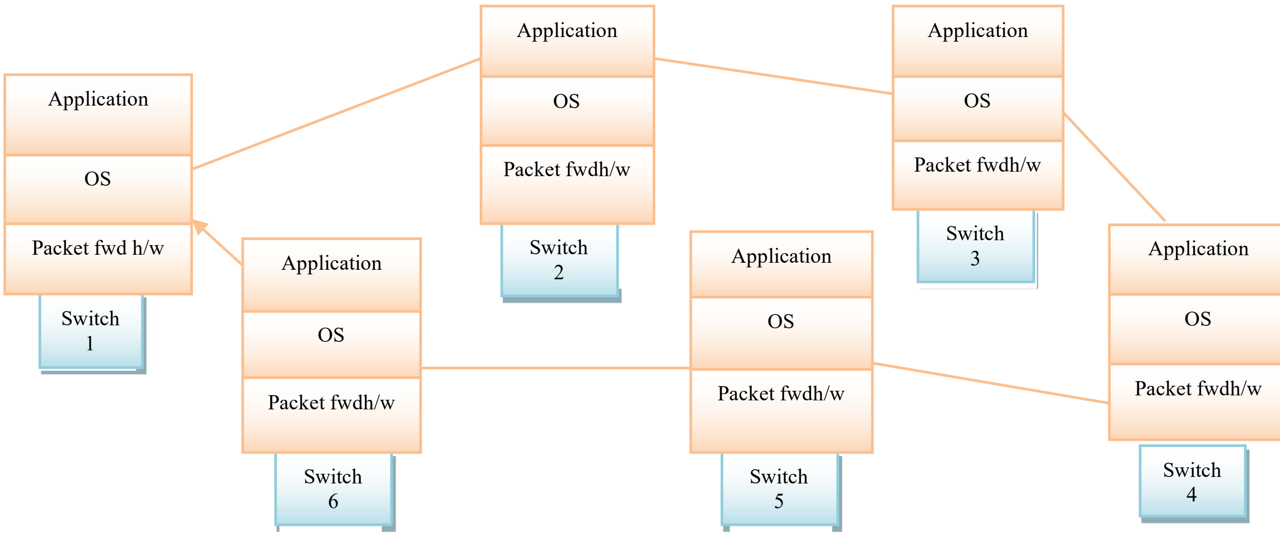

Fig 3: Limitations in traditional architecture

Then emerged the concept of Software Defined Networking to control security policies in a centralized manner. It defines the control logic in a centralized manner and separates it from the hardware switches i.e. it separates data plane and control plane. Rule placement and controller placement are the two main challenges of this approach. A flow table is maintained at every switch and switches forward packets based on flow rules. A switch sends a PACKET IN message to the controller when it receives a request for which no flow rule is present.

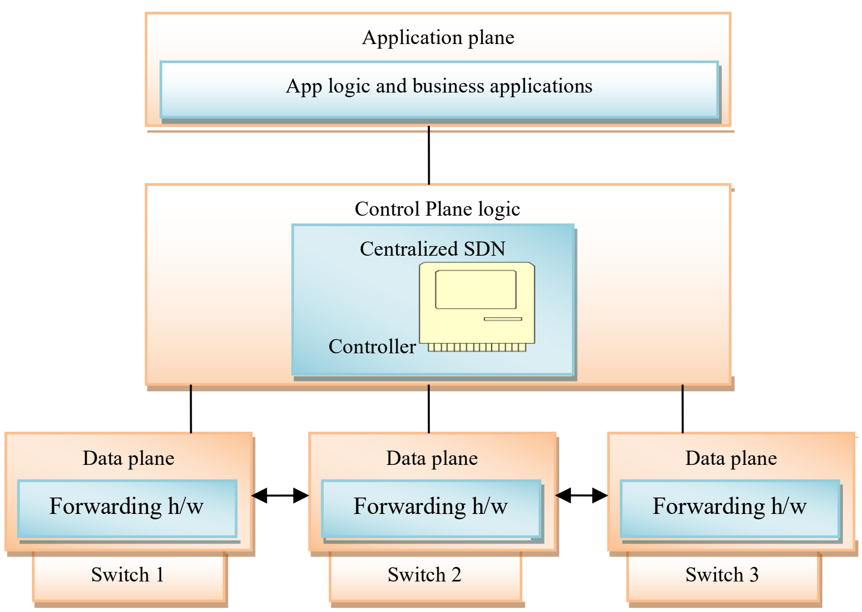

Fig 4: SDN Architecture

But as the size of ternary content addressable memory (TCAM) is limited at the switches so a limited number of flow rules can be inserted. OpenFlow is a protocol used to communicate between data plane and control plane. It is one of its kind that is available to describe the rule placement. Using OpenFlow, a software based assess is granted to the flow table which in turn instructs the switches and routers to direct network traffic **[19]**. Indigo, Pantou, LINC, of13softswitch and Open vSwitch are the popular OpenFlow switch software. Southbound API is used for communication between control plane and application plane whereas communication between data plane and control plane is done via Northbound API. East-Westbound API are used for communication among multiple controllers in the control layer. The controller defines the flow rules and can handle 200 requests in a single thread. If there is a large network and the number of controllers is very small then the network might be congested with PACKET IN messages. The control decisions can be taken either in a distributed manner where each subnet is being controlled by separate controller or in centralized manner where there is a single controlling the whole network. Pox, Nox, Floodlight, ONOS, Open Daylight are popular software for controller placement **[20]**.

The advantage of integrating SDN with IoT is that the information collection, analysis, decision making is simplified and intelligent routing decisions can be deployed using SDN. Wireless sensor nodes and networks can be controlled and network performance can be improved using SDN-based applications. It controls end devices such as sensors and actuators. SDN improves the service logic and orchestration between devices and protocols. It takes care of rule placement at access devices through various approaches like Odin, UbiFlow and Mobiflow. Traffic engineering at backbone networks while considering issues like mobility and heterogeneity of end users is also taken care by SDN.

4.CONVERGENCE OF IOT AND CLOUD COMPUTING

The two spheres of Cloud and IoT have seen an individualistic expansion. A novel paradigm called ClouIoT paradigm where Cloud and IoT are unified together is considered to be miraculous which enables a large number of application scenarios. IoT is based on insightful and self-configuring things associated in a dynamic and global network infrastructure. IoT is generally characterized by small gadgets with limited storage and processing capacity and associated issues like performance, reliability, privacy and security **[21]**.

Cloud computing is a ubiquitous pay per use model which enables convenient, on demand network access to a pool of computing resources that can be rapidly allocated and released with low management effort. It has the three very basic service models i.e. Software as a service (SaaS) like Google Apps, Salesforce, Learn.com, Platform as a service (PaaS) like Microsoft Azure, Google App Engine, Infrastructure as a service (IaaS) like Amazon EC2, Gogrid, iland, Rackspace Cloud Servers **[22, 24]**. Cloud computing has inexhaustible proficiency in terms of storage and processing and partially solves most of the IoT issues. Sometimes, the convergence of cloud and IoT enables an everything as a service model.

Immense potential and resources of cloud can compensate for the technological constraints of IoT.

Table 1: Reciprocity and assimilation of Cloud and IoT

Cloud	IoT
Ever present (Resources usable from anywhere)	Pervasive (Things / Gadgets placed everywhere)
Primary objective is virtualization and storage	Primary objective is connectivity
Use Internet for service delivery	Internet as a point for intersection
Possess virtually unlimited computational / Storage capabilities	Limited or no storage capabilities
Virtual resources	Real world things
Manages huge or big data	Source of creating big data
Focussed on lowering the cost associated with data storage	Focussed on enabling automation

Cloud computing not only offers an adequate solution to enforce IoT service management but also yields composition as well as applications to capitalize on the data or things produced by them. Cloud can also have benefits through IoT by stretching its capacity so that real world objects can be dealt with in a more dynamic and distributed fashion. It can also be utilized for dispatching new services in real life scenarios **[23]**.

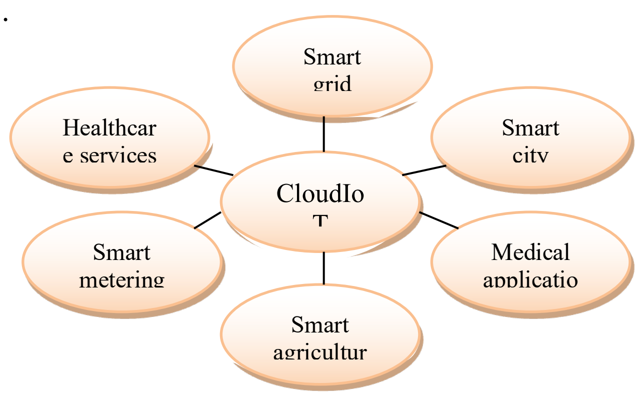

Fig 5: CloudIoT application areas

With the insistence of homogenization of cloud and IoT increasing rapidly, a number of simulators facilitate predeployment test of services. Different cloud simulators practised today are CloudSim, CloudAnalyst, GreenCloud, iCanCloud, GroudSim, DCSim. The adoption of CloudIoT paradigm facilitates new schemes for smart services and applications by extending cloud services **[21]**.

(i) Sensing as a Service (SaaS)

(ii) Sensor Event as a Service (SEaaS)

(iii) Sensing and Actuation as a Service (SAaaS)

(iv) Database as a Service (DBaaS)

(v) Data as a Service (DaaS)

(vi) Sensor as a Service (SenaaS)

(vii) Identity and Policy Management as a Service (IPMaaS)

(viii) Ethernet as a Service (EaaS)

(ix) Video Surveillance as a Service (VSaaS)

OpenStack, launched as a joint project of Rackspace hosting and NASA in 2010, is an open source and preconfigured collection of open source technologies to create a cloud infrastructure which can be installed manually or using scripts like Devstack **[25]**. It can be considered Infrastructure as a service (IaaS). The various components in OpenStack are:

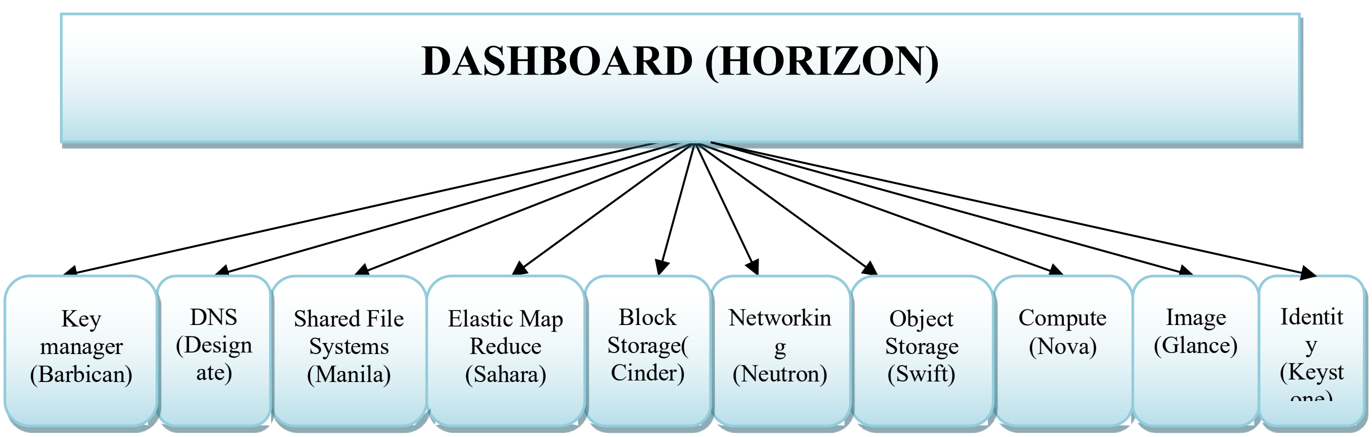

Fig 6: Components of OpenStack

It renders a platform to create software service and allows end users to create and deploy virtual machines. New instances can be easily configured to run other cloud components.

5. IoT WITH FOG

Fog Computing or Fogging, a term coined by CISCO, is the idea of extending the cloud nearer to IoT devices. Nearly 40% of the world's total data will be generating from sensors alone by 2020 as

2.5 quintillion bytes of data is generated per day. Due to the increase in device density every day, the prevailing cloud model is unable to handle the requirements of IoT and, therefore, various issues to deal with are:

Volume: By 2025, near about 50 billion of devices will be online.

Latency: Time taken by a data packet for a round trip. This is a critical factor as a millisecond can make a considerable impact and latency will rise. It is of utmost importance while handling a time sensitive data.

Latency= $T_{\text{from device to cloud}} + T_{\text{data analysis}} + T_{\text{from cloud to device}}$, where T=Time.

*Bandwidth :*Population of IoT devices is massive and continuously increasing. The traffic produced will be gigantic if whole data generated by them is sent to cloud for storage and analysis. This can also consume almost all the bandwidth.

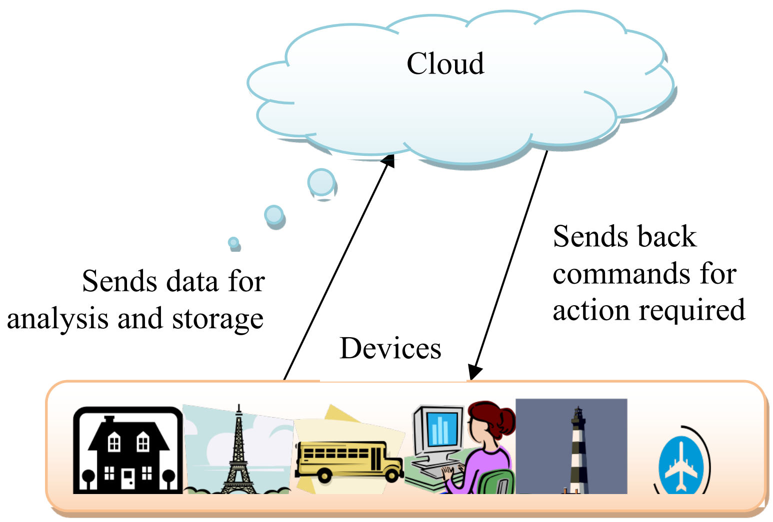

Fig 7: Present day cloud model

Fog works as transitional layer between IoT devices and cloud environment.

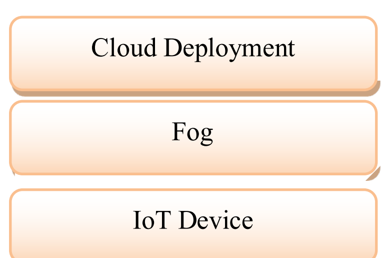

Fig 8: Fog as middleware between Cloud and IoT

If there are huge number of devices which are subject to extreme conditions and separated by large geographical distance but their data should be analysed within fraction of seconds. In that case Fog Computing comes into picture. Data from sensors is processed in fog before being sent to cloud which saves bandwidth, reduces latency and storage space of the cloud **[26]**. Many fog nodes can be present. Routers, embedded servers, switches, video surveillance cameras can work as fog nodes which are deployable anywhere inside the network **[27]**. Nodes in fog work depending on the kind of data they receive.

Data can be divided into three types based on sensitivity:

(i) time sensitive data

(ii) less time sensitive data

(iii) non time sensitive data

Table 2: Working of Fog

Measures	Fog node closest to devices	Fog aggregated node	Cloud
Data type	Time sensitive data	Less time sensitive data	Non time sensitive data
Inferencing time span	Fraction of second	Seconds to minutes	Hours to days/week
IoT Data storage duration	Ephemeral	Few hours, days	Months to years
Geographical coverage	Very local	Wider	Global

The nearest fog node ingests the data from the IoT devices. Time sensitive data that requires quick analyses i.e. within fraction of second, are analysed at the nearest node. Respective decision or action is sent to the device which stores the summary and transmits the same to cloud for future usage. Less time sensitive data is sent to the aggregated fog node, the required decision or action is sent to IoT device via the nearest node. The data that can wait for hours, days or even weeks is known as non-time sensitive and are generally sent directly to cloud for future reference or analysis **[27]**.

Fog computing has numerous advantages when collaborated with Internet of Things **[28]**:

(i) It provides better security

(ii) It reduces the bandwidth consumption

(iii) It reduces latency

(iv) It stores confidential data in their local servers thus providing better privacy

(v) It can be deployed in remote areas anywhere and programmed according to customer needs

(vi) Fog nodes can be mobile, thus supporting mobility

5.1 Applications

1. *Real time health analysis* :Chronically ill patients can be monitored in real time and alerts can be sent to respective doctors immediately during emergency.

2. *Intelligent power efficient system:* It entails the detailed report for power consumption every day and suggests economic power usage plan.
3. *Real time rail monitoring:* It monitors the track conditions in real time which improves safety and reliability.
4. *Pipeline optimization:* Transportation of gas and oil through pipeline is eminent. There, increased latency is unacceptable, as it is necessary to monitor pressure, compression and flow in real time.

6. IoT REALIZATION AREAS

6.1Healthcare

Healthcare is a critical part of life. sadly, the regularly aging population and the related upward thrust in chronic contamination is placing widespread pressure on present day healthcare systems. IoT has the potential to relieve the pressure on healthcare systems. Different sensors can be employed on the patients' body and data received can be transmitted to the short or long distant doctors. Consultation received can be used to cure and can also be saved in the cloud for future reference **[29]**.

6.2 Smart City

A smart city is basically an urban system which uses information and communication technology to make the infrastructure more interactive, accessible and efficient. Smart cities mission aims at enhancing the lifestyle by localized are development and utilization of technology that leads to smart outcomes. It caters a clean and sustainable environment, a satisfying quality of life to residents and applications of smart solutions. The need for growing smart cities arose due to fast depletion of natural resources, rapidly growing urban population, etc. Enormous data is produced at a regular interval of time in a smart city environment and data from multiple sensor sources is combined and then drawn the inferences from the fusion of this huge amount of data **[30]**.

The core infrastructural elements of a smart city encompass:

(i) Robust IT connectivity and digitization: The whole infrastructure of a smart city should be interconnected so as to provide a fast solution to real world problems.

(ii) Good governance, especially e-governance and citizen participation: It inculcates the management of separate public services like banking, surveillance, emergency services and government agencies, etc.

(iii) Sustainable environment: The information retrieved from the sensors should be processed rapidly so as to enable the right decision making.

(iv) Smart Energy management: It includes the smart metering systems, the allocation and distribution of energy, etc.

(v) Smart parking lots: It should realize the detection of vacant slots and auto routing of vehicles to empty slots, reduces traffic congestion, fuel consumption and pollution by keeping off the unnecessary lingering vehicles.

(vi) Smart health: Remote check-up and diagnosis of patients, on body sensors for accurate health monitoring and auto alert generation to the concerned doctors for emergency medical situations.

(vii) Pollution and calamity monitoring: Auto alert generation when the pollutants in the air reaches above threshold, weather monitoring, etc.

(viii) Smart agriculture: Monitoring of crop health status, any infection in crops, auto application of fertilizers and pesticides, etc.

6.3 Smart Homes

In smart homes, a seamless integration of various devices using wired and wireless technologies is done which creates a highly personalized safe home space. The things in the house are connected which allows ease of use for household systems. Smart home depends on smart appliances, smart meters and home power generation. The network within a home which enables remote access and control of devices and systems is called home area network (HAN). It may be wired using telephone lines, optical fibres or wireless which may be battery operated where no energy harvesting is needed or battery free using connecting technologies such as ZigBee, Z-wave, 6LoWPAN, Enocean **[31]**. The various HAN standards are:

(i) Universal Plug-and-Play (UPnP): It is application layer web-based technology which provides automatic discovery of devices.

(ii) Digital Living Network Allowance (DLNA): It connects cable-based networks with wireless networks for sharing the network resources domestically, their control and access.

(iii) Konnex: An important standard for building network utilizing power lines, coaxial cables, twisted pair, radio frequency, etc.

(iv) Local Operations Networks (LonWorks): Every device is embedded with a neuron chip and splits device groups into intelligent elements which communicate with a physical communication medium.

6.4 Smart vehicles

In this implementational area the vehicles are equipped with sensors which can communicate with other devices inside the vehicle, communicate with another similar vehicle, and with a fixed infrastructure **[32]**. A new paradigm i.e. V2X (Vehicle to everything) mainly designed for highly mobile devices is introduced where a vehicle is connected to each and everything. The vehicles interconnected together sharing a diverse range of data is called Vehicular Ad hoc Network (VANET) based on Dedicated Short-range Communication (DSRC) and Wireless Access in Vehicular

Environment (WAVE) **[33]**. A three-layered architecture called Brain and Body Architecture is proposed which is an in-vehicle network architecture.

6.5 Smart grids

As per the definition given by NIST, Smart grid is a modernized grid which uses two way communication and control capabilities to enable bidirectional flow of energy using leading to an array of new functionalities and applications **[34]**. Consumer participation is anticipated through which the real time monitoring of consumption is done. Real time pricing is obtained by using smart meters where the final bill paid by the customers depends on the inflow and outflow of energy. Load forecasting and self-healing is made possible through the application of smart grids **[35][36]**. Different networks associated with smart grids are HAN, Neighbourhood Area Network (NAN), Wide Area Network (WAN), IP network, Sensor and Actuator Network (SANET).

6.6 Agriculture

Regardless of the belief about the agricultural system, the truth is that today's agriculture is data-oriented, unique, and smarter than ever. The rapid emergence of the IoT based technology has redesigned almost each sphere such as ''smart agriculture''. Technology is helping the farmers at every sage from sowing to harvesting. Data regarding the climate, soil properties and others is analysed, suggested methods are applied to increase the production **[37]**. Various kind of sensors can be implemented to analyse the various important factors related to farming and data can be utilized for enhancements.

6.7 Activity Monitoring

The physical activities of humans can be monitored by deploying some wearable sensors. It proves to be very helpful when it comes to provide better quality of life and safe guarding humans. It is also successful in providing continuous monitoring support. Various sensors like accelerometer, Gyroscope, GPS, Cameras, etc. can be utilized to attain activity monitoring.

7. FUTURE DIRECTION

In IoT, the devices can transmit information over a network to other local or remote devices, so the privacy of data being transmitted cannot be compromised. The data should be stored and be accessible by the authorized nodes only. As the number of devices being connected to internet is growing day by day so a new addressing scheme should also be considered as this is an area where utmost care is needed to name and identify devices. The various and different technologies like RFID, IEEE 802.15.4, ZigBee, 6LoWPAN related to IoT should also work hand in hand. The time sensitive data should be analysed on a priority basis for faster decision making so the fog computing should be integrated in a more effective and efficient manner. A new research and novel paradigm for managing the huge big IoT data coming from the objects or things should be proposed.

8. CONCLUSIONS

IoT is a new technological field where things around us can sense information and communicates the sensed information over a network to other devices to resolve the real life issues. In the coming years, there will be around 50 billion devices being connected to the Internet. So, the volume of data produced will be enormous. The IoT has enabled the vision of 'everywhere, every time, everything' communication. IoT is the future of the Internet which has added a new prospective to internet by letting the communication between humans and objects. In IoT the various data protocol are publish-subscribe based. In this paper, firstly the definition of IoT and thorough discussions on the basics/ principles behind the IoT are unravelled. The communication technologies indulged in IoT are ZigBee, IEEE 802.15.4, Z-wave, ISA, Bluetooth LE and many more. Next wireless sensor network and various protocols are discussed. Then, the principle of Software-defined Networking which focussed on separation of control plane and data plane is elucidated. It explicitly explains the role of integration of cloud computing and fog computing to the IoT so the better and fast decision making can be attained. Diverse application areas of IoT are also highlighted. In contrast to other IoT articles/survey papers, the main contribution of this paper is that it elaborates and highlights all the terminologies and technologies related to IoT. New researchers can find a detailed explanation of IoT, its enabling technologies, associated challenges and the various areas where it is being used, as a whole.

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