**IOT Platform and Architecture**

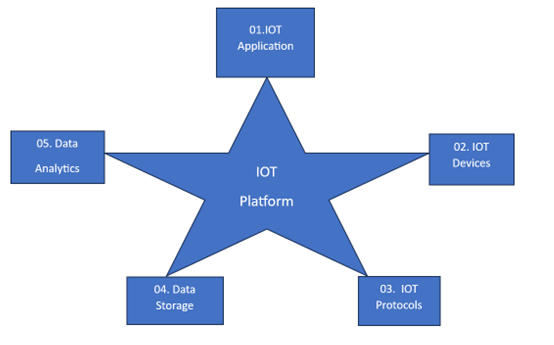
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**1.Introduction**

With the rise in internet accessibility the people around the globe are trying to exploit its usage for various applications. One such field where internet is finding its place is IOT (internet of things). IOT refers to connecting different devices to each other through the internet. It is revolutionizing the digital world enmasse. The IOT is a multiple-layer platform that carries out direct management, automating and catering of devices within the Internet’s domain. IoT platform relates to a set-up of IoT elements which includes gateways, sensors, actuators, communication protocol, cloud server setup, and end-user application interface. With the speedy evolution in the industry, there are many different ways to device an IoT platform. It is a convenient platform for apprentices and designers for instant use, which runs at an incredible speed. It is a remote device allowing users to manage the linking between hardware and application devices. Having unique features like cloud and various gateways, it has a good scope for the business development. Various stages of IOT Platform are shown in Figure 1.



**Figure 1: IOT Platform**

**1.1 IOT Platform and Architecture**

“An IoT Platform is a fusion of cloud-based services and applications used to monitor, manage and interact with smart, connected devices.”

We need to have various sets of policies and apparatuses for actual disposition of IOT. The various techniques and apparatuses used in the explicit realm for the unambiguous IoT solution, is known as an integrated

IoT platform. IOT Platform allows to deploy and run application. It is a combo of the hardware systems and software programming upon which other applications can run. Platform comprises of hardware which allow operating system to reside.[1] This operating system allows applications work above it by offering essential execution atmosphere. IoT platforms provide a complete set of generic claims, independent functionalities to build IoT applications. [2] Only a specific service can be set, as there is only one communication link between devices of one type with another device. A need of some common standard application platform is a must for devices of multiple types to hide the heterogeneousness of numerous devices, by paving a shared working environment to them. [3] An IOT application platform is a real solution as it resides over cloud. Due to connectivity with the cloud, IOT platform interprets data into useful information. It offers various ways to implement business use cases and permits prophetic maintenance, analytics, pay-per-use and also real time data management. IOT application platforms offer a whole set for application growth to its distribution and maintenance. IoT platform is generally assembled within the intricate bionetwork of tools, package(software) and the stock, dealing with diverse related issues, straddling from the M2M connectivity, to the data analysis and the visualization. The utmost topographies of the diverse areas are immense computing and security.

Stankovic [4] emphasized the following directions for IoT application platform based on research work:

1. massive scaling (which involves to address, discover, architectural models supporting the anticipated heterogeneity),
2. Framework and dependencies (involving IoT applications, execution, determining interfering problem in opting the utility devices for diverse apps by various kinds of multiplexing, requirements encompassing applications specifically for the safety purposes),
3. generating information and huge amount of data (knowledge formation, real-time data elucidation, innovative techniques, confidence levels for believing data, consistent data analysis),
4. augmentation and susceptibility,
5. safekeeping (finding and analysis of attack and disposition of other means without fail),
6. privacy (assess needs contrary to policies, resolution of the various policies)
7. individuals in the loop (displaying people’s behaviours, requirements and controlling).

The skills and values for the purpose of the IoT devices, engineering and deliverance are in the initial stage of evolution, so the IoT platforms must hold a role of IoT experimentation facilities. Gluhak [5] recognized the necessities for the coming generation with investigational research amenities for the IoT:

1. scalability - “For supporting the number of nodes: minimize human intervention, maximize plug-and-play configuration and automatic fault management”.

2. heterogeneousness - “For the management of devices and to ease programmability of heterogeneous devices”

3. repeatability – “between different test beds; agreements on standards”.

4. partnership – “with the other test beds/ experiments: For the shared framework for authentication and the interoperability”.

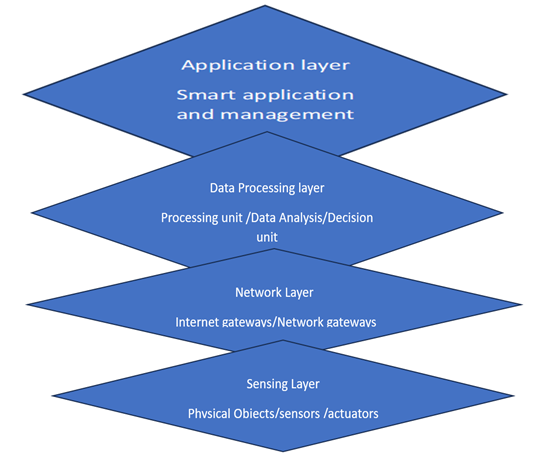
5. concurrence- “virtualization of the devices and numerous experiments used for a device”.

6. experimental environment – “strength to the environmental conditions”.

7. flexibility- “For handling system dynamics and movement of devices”

8. The impact and user involvement- “For multi-modal mechanisms for the user feedback and automatic detection of conditions where the user behaviours influence the data validity”.

As there are different application areas of Internet of Things, it is designed and developed accordingly. Though there is not a well-defined architecture followed universally. The architecture of IoT mainly is based on the functionality and implementation in different sectors. However, there is a basic process flow based on which IoT is built. Figure 2 shows the various IOT architecture.



**Figure 2: Stages of IOT architecture**

**Various layers/stages of IOT architecture are listed below:[6]**

1. **Sensing Layer –**    
   The first layer of the IoT architecture is sensing layer which is responsible for collecting data from various sources. This layer comprises of sensors and actuators that are positioned in the environment to gather information about the temperature, humidity, light, sound, and various other physical parameters. These devices are linked to the network layer through wired or wireless communication protocols.
2. **Network Layer –**    
   The network layer of an IoT architecture offers communication as well as connectivity between devices in the IoT system. This layer includes protocols and technologies that allow devices to link and communicate with each other and also to the wider internet. Various examples of network technologies commonly used in IoT include Bluetooth, WIFI, Zigbee and 4G, 5G networks. This network layer also includes gateways and routers that act as mediators between devices and the wider internet, and also have potential to offer security features like encryption and authentication to guard against unauthorized access.
3. **Data processing Layer –**    
   The data processing layer is the third layer of IoT architecture which involves both the software and hardware which are accountable for collecting, analysing and interpreting data from the IoT devices. This layer is also responsible for receiving the raw data from the devices, processing it and then making it available for further investigation and then action. The data processing layer includes a variety of technologies and tools like the data management systems, analytics platforms and also machine learning algorithms. These tools are used to extract the meaningful insights from the data and make decisions accordingly on that data. One of the examples of a technology used in the data processing layer is a data lake, which is a centralized storehouse for storing raw data from the IoT devices.
4. **Application Layer –**    
   The application layer of the IoT architecture is the topmost layer which interacts directly with the end-user. It is highly responsible for providing user-friendly interfaces and functionalities that enable the users to access and control IoT devices. The application layer includes various software and applications such as mobile apps, web portals, and other user interfaces that are intended to interact with the underlying IoT infrastructure. Also, middleware services are included in this layer that allow different IoT devices and systems to communicate and share data uninterruptedly. The application layer also comprises analytics and processing capabilities that allow data to be analysed and transformed into meaningful insights. This includes machine learning algorithms, data visualization tools and other advanced analytics capabilities.

In nutshell components of Iot architecture can be placed as :

(1) Sensors/ Devices

(2) Gateways and Networks

(3) Cloud based management service layer

(4) Application layer

**1.2 Various IOT Platform**

IOT support platforms are listed below.[7]

**Arrayent Platform:**

Composed of four components this IoT platform provides liable service. Link/i.e connect Agent is a microcode, a trivial agent installed in machines/devices (huge microcode updates enabled). This agent helps data to connect through the Cloud by making use of 128-bit Advanced Encryption Standard (AES) encryption which is highly sensitive. Each of the device having its private digital replica in the Connect Cloud organizing the virtual devices which are connected with mobile apps. Mobile template is aimed for expansion of apps which organize the allied devices. It also uses engines for dealing and distribution generated signals that can also then activate reply actions in the product that produced the alert. Lastly the acumen offers safe access to data through the dash, data- streaming, consignment exports and the data connections as well.

**Autodesk SeeControl Platform:**

It offers IoT cloud service used for virtualization, connecting with reporting devices and also usage of analytics to reveal their data. Coding less, drag -and-drop methods are implemented. This Platform is focusses on the necessities of the manufacturing industries, making performance data of the products then forecasting a product failure, performing maintenance and enhancing supply chain and also material renewal costs. This Platform provides a large library of prevailing protocol and vendor device adapters. Its facility also includes light Enterprise Resource planning modules and the business management tools etc.

**Axeda Platform:**

Axeda acts as a connectivity middleware for the easy connection of machines/tools and the devices to the cloud. This Application empowerment platform abridges expansion of IoT apps, with the skills like the management of data, Engine Scripting, Framework Integration, Software development kits and the web services for retrieving data and the apps in the cloud without any issue. Connecting machine management applications enable the distant surveillance, operation, service and the regulator of distant devices. Competences includes the software (client and macrocodes) delivery and the configuration management as well.

**Bugswarm Platform:**

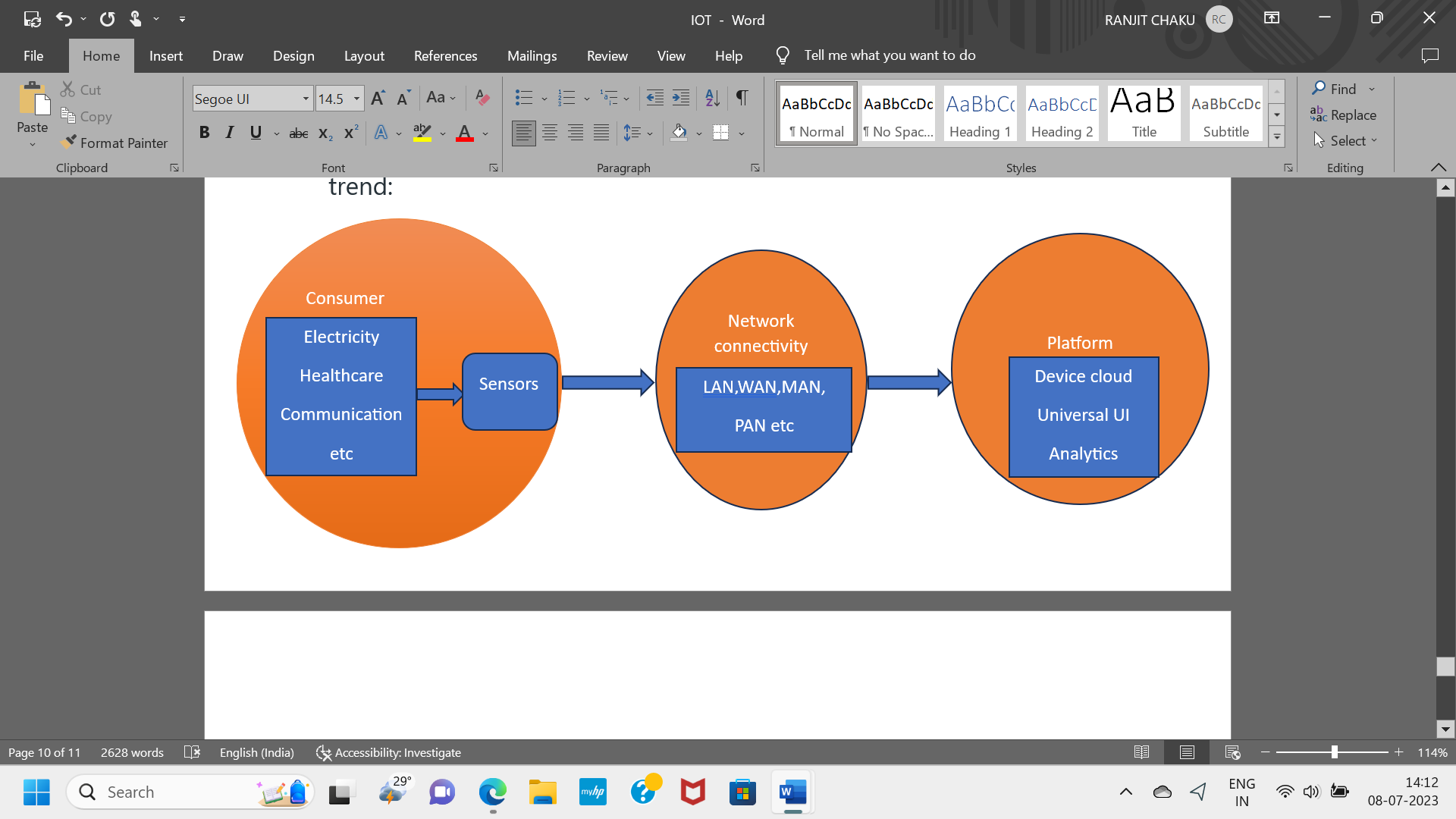
It acts as a trivial means that can gain the data and then control the devices using the software like the Java-Script or the plain HTTP. It states a “swarm” – the system of resources for communicating to the other resources within the system, corresponding to the well-defined access policy. Resources join through HTTP, which are not only confined to devices but also web or mobile applications. For connecting prevailing devices as a resource to a swarm various thing like the Device-specific platform, Client-side platform applications and device connectives are made available for the use. Specific devices send the private messages loaded with the list of skills and services to all the swarm members. Also, the other resources which are concerned about the services are liable to direct a feed request to the device, replying with a feed response.

**Carriots Platform:?>**

This platform acts like a compiler; enabling connectivity between various types of devices to the web connectivity sending a cascade of the data, by making use of the Message Queing Telemetry Transport (protocol),Client forURLs (software), Poster, RESTful API. A client installation for individual protocols is desired for the device. Also, a Trigger component is established and installed to perform operations on the data. For status checking, configurations managing, microcode updating the device control and maintenance are enabled. Further development is carried by using Java Carriots Software development Kits (SWKs), by introducing codes to the specific fields in web application. Free use is enabled but with limited functionality for up to 10 devices.

Digital Service Cloud:

It is an open IoT platform, which permits IoT innovators to own their clients the way the clients own their products. Supporting product launches, start-ups, worldwide technological brands and the product innovations as well. This platform paves way for the process of a new innovation. One can build customised IoT solutions by connecting devices and using plug and play dashboard by using the readymade infrastructure provided by Digital Service Cloud. Then, only one has to monitor and manage the product over lifetime. It helps to connect the artefact with a web of the millions of devices. DSC foundation involves the following sequence:



**Figure 4: Digital Service Cloud Platform**

The IoT application is readily available on the cloud and can be connected to the consumer devices equipped with various sensors thereby communicating with the application. For connecting the device over cloud various networking-connectivity techniques’ do exist. Cloud delivers device management and application development.

**Evrythng :**

The natively digital identity management platform, also referred as “Product Relationship Management” (PRM) platform. Semantic data store is used to modify dynamic data profiles – digital identities of the products, such that they can exchange data with sanctioned applications.

**Exosite :**

The cloud-based IoT platform which offers M2M connectivity and data visualization tools and services. Open application programming interface (API) is accessible for advanced data processing and integration with enterprise applications. Groove Streams is data analytics cloud platform, allowing data collection from multiple platforms which includes IoT devices. Open API is used to send data streams at a fixed or randomized intervals or as a fixed value in the form of the point streams. Data is reorganized as the Derived Streams, or can be envisaged with the customizable charts and graphs. It is an open access platform. Various organizations, clients and increased/scalable data are the prominent features available with this platform.

**Google Cloud Platform:**

Coding, testing and installation of applications for inventors with vastly scalable and dependable infrastructure is provided by Google and itself uses it. However, developers need to devote more attention to the code the rest of the issues regarding infrastructure, computing power and data storage facility are handled by the Google.[8] Google is one of the greatest and the popular IoT platform as it provides: Fast worldwide networking, Google's BigData tool applications, Strategy like pay as you use. The various available services of cloud like the BigQuery, PubSub, RiptideIO, Firebase, Connecting Arduino and Firebase and Cassandra on Google Cloud Platform etc are supported by Google Cloud platform. Some attributes of Google cloud platform are: 1. Depends on Google's set-up 2. Scalability 3. Computing 4. Packing services 5. Security assurance

**IBM Blue mix:**

The IBM Cloud platform fuses platform as a service/ PaaS with the infrastructure as a service/ IaaS to deliver an integrated experience. The platform is developed to scale and also aid both small developing groups and organizations as well as the large enterprise businesses. Its data centres are Globally deployed around the world, moreover the solution one builds on IBM Cloud spins around fast and has high reliability.

IBM Cloud provides the most open and secure public cloud for business with a next-generation hybrid cloud platform with advanced data and AI competence. Solutions are accessible depending on ones needs for working in the public cloud, on-premises, or the combination of both.

IBM BlueMix platform and IoT foundation jointly offers powerful application admittance to IoT data and devices. Thus, supporting the speedy development of analytics applications, visualization dashboard, and mobile IoT applications as well. Firstly, one needs to create IoT based application with IBM Bluemix and then the IBM provides the REST and secure API to attach device data with the applications. IBM IoT foundation is the where one can set up and manage ones connected devices. IBM IoT foundation uses Message Queuing Telemetry Transport protocol to securely handover device data to the cloud. [9] Some attributes of IBM Blue mix are: 1. Authoritative web control panel 2. Device Registering 3. Scaled connectivity 4. Safety 5. Proper storage of the data

**Ifttt (If This Then That) Platform:**

Ifttt platform is non-native IoT; it acts like an interoperability-as-a-service platform which permits operators to form chains of conditional statements, known as “recipes”, which are implemented upon the specific events documented from the diverse services. This platform permits clients to generate their own recipes, which can also comprise actions from the various devices. Few examples of IoT related recipes are: “delay watering your garden if it’s going to rain tomorrow”, “receive and emergency call if smoke is detected”, and others. Zapier and the Yubnub are some replacements for this service.

**Kaaproject Platform:**

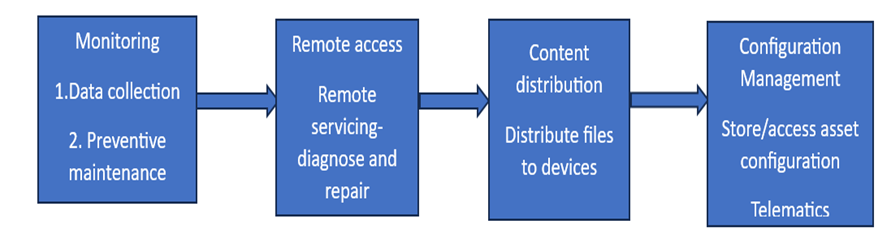
It is an open-source IoT middleware platform which enables the management and the maintenance of device inventory, and also the real-time communication between the devices. It promotes use of structured data. It offers software development kits (SDKs) that are implanted into devices. Comprehensive keys which already exist for the, Raspberry Pi, Android, IoS and like many other platforms as well. This Platform is combined with the present data processing techniques like Oracle, mongoDB, Hadoop, and others.

**LinkSmart Platform:** Formerlydeveloped by Hydra EU project, LinkSmart Platform is an open-source middleware platform and also a service infrastructure for the building up of IoT applications. This project was introduced by Fraunhofer FIT(Fraunhofer Institute for Applied Information Technology). It comprises of the Device Connectors for mixing the various devices with diverse operations for specific devices, Resource Cataloguing for managing the devices and also resources they are exposed to, Service Cataloguing (services which are used to access devices and resources) and Global Connect tunnelling facility that permits accessibility to the devices outside the limitations of a private networking.   
**Mbed Platform:**

Mbed platform treats all its connecting devices as embedded devices and focusses on tighter integration. It comprises of the domestic mbed i.e open-source Operating System, architecture which is event-driven single threaded that is scaled down to the simplest, least cost and lowest power consumption devices. Mbed supports the devices which are based on the Advanced RISC Machine and the Cortex-M microcontroller. The security, connectivity and the manageability which opts for the Open Mobile Alliance Lightweight M2M(protocol), a popular protocol used for the monitoring and supervision of the embedded devices are the Key or the prominent features lying with this platform.

**Microsoft Azure cloud:**

Internet of Things for the commercialisation starts with the equipment’s that are involved in the business and affect it the most, according to Microsoft. Starting from the substructure of the business by adding devices and services into it with technological expansion, will lead one to get insight of the information related to that and to make powerful and informative business decision. Thus, IoT is essentially Internet of Your things. The portion of data about the customers, sales, business procedures or other inventory data is valued asset to one’s organisation and it can help one to power the business. Microsoft offers Microsoft Azure Intelligent System Service forming a unified platform and services that shapes Internet of Things systems and applications by assembling, storage and processing of the data. It is the Cloud that offers solution for the data storage, data processing, data consumption and data study on real time/ latent data. IOT application provides monitoring, remote access, content distribution and configuration management facilities for connected devices.



**Figure 3: Various steps involved in Microsoft Azure Cloud**

Microsoft Azure cloud connects of millions of devices and sensors with IoT application, thus providing big data analysis, social as well as business integration and dash boarding tools for IoT application to shape an IoT solution. Some key attributes are: 1. Figures out on what is already established 2. Does minor changes with bigger reflections 3. Reliable support 4. Skilled in growth and distribution 5.Connectivity to any device 6. Trained allies and commanding innovation 7.Easiest way to transform business

**Nimbits:**

It is a rule engine platform for M2M connectivity and also provides data logging service. For evolving Java it offers nimbits.io i.e. free software Java library also Web and Android solutions using Nimbits Server as a backend platform. Geo and time engraved data and execution guidelines on that data like calculations, email alerts, push notifications and like others are assembled by backend platform. It also makes the availability of the Free and Enterprise editions of the server. The Particle.io offers the computer hardware development kits and building up the macrocodes within the devices, by making use of web-based IDE and installing the macrocodes. Later, from the collected data ParticleJS and Mobile SDK libraries are used to build web and mobile apps.,

**PTC ThingWorx Platform:**

Here, each device is characterized by so-called Thing Template, defining properties (for instance, mass), services (for instance, posting to Instagram) and events (for instance, malfunction). The devices have the agents to join with the IoT platform; various agents address the different types of devices. Things, business logics, visualizations, data storage, collaboration and security required for generating IoT application are modelled by the Composer applications/web-based applications. The assemblage/mashups can be gathered by the means of various thing templates, namely, UI widgets pre-wired to the thing templates. Later, the mashups are used for interactive IoT applications, real-time dashboards, collaborative workspaces and mobile interfaces as well. Thus, enabling definition, also, for execution of the processes a BPM component is involved, which starts with an alert or even a event for the remote connected devices. For facilitating remote diagnostics, control and scheduled software updation of things device asset management tools are involved. It can be used for free but with limited functionality.

**SensorCloud Platform:**

It is a cloud based IoT platform used for procurement, visualization and investigation of data. This platform intrinsically chains the connectivity with LORD MicroStrain’s wireless as well as wired sensors. Also, Visualization tools are available. Simple alerts are setup which are activated through the data threshold values. Provision of MathEngine analyatics machines/tools with a very simple interface facilitates operations like FFTs, smoothing, filtering and interpolation etc.

**ThingSpeak Platform:**

Like SensorCloud, ThingSpeak Platform provides open channels to the available data from the different devices which are published by the users. Thus, enabling actuation, talking back to the device which is carried over by the Hypertext Transfer Protocol (HTTP).

**Zetta:**

The Zetta being an open-source platform was established in Node.js for generating IoT servers that run across geo-distributed servers and cloud. It merges RESTful API, reactive programming and web sockets as well. This merger is apt for assembling various devices into data intensive and real time applications. One can run Zetta in the cloud, on PCs and also on single board computers without any issue. For creating geo-distributed networks, Raspberry Pi(operating system) and PCs together are allied with cloud platform like Heroku with the help of Zetta. Zetta having the capacity to diverge any device into an API. Zeta provides the devices a RESTful API locally and also in the cloud by collaborating with microcontrollers like Arduino and Spark Core. Zeta being developer friendly gives direct access of protocols and conventions to developers so that they can effortlessly and efficiently transform sensors, actuators and controllers into innovative IoT applications and systems without major issues. Architecture of Zetta is optimized for real-time applications, allows monitoring of device and system behaviour in code and using visualization tools to get actionable insights. Zetta lets one to assemble smartphone apps, device apps and cloud apps together into huge and intricate systems. Home automation, smart transportation and wearable computing are some examples of this system. [10]

**Yaler:**

This platform offers an infrastructure, safeguarding access to embedded systems and also works with any device with a Transmission control protocol socket and is a pay-as-you use platform. Yaler is one of the cost-effective solution appropriate for enterprise applications, offering a hosted service on devoted relay instances. A fixed -yearly- fee per relay instance helps one to reach out to the number of devices connected to a dedicated/devoted instance. This relay service also holds secure sockets layer and transport layer security encryption. The incorporation of theYaler.net which is a cloud-based connectivity services, enables a protected ad hoc assembly for data streaming.[11] It is mainly designed for providing a more stable, secured, and high-performance execution environment for the applications.[12]

**1.3 Benefits of IOT**

IoT provides a number of benefits to organizations, permitting them to:

1. Monitor their overall business developments
2. Expand the customer experience
3. Saving time and money
4. Boost employee productivity
5. Integrating and adapting business models
6. Making better business decisions
7. Generating more revenue.

**1.4 Discussion**

The main characteristics of IoT platforms are: First is connectivity followed by the monitoring and maintaining of the devices which includes microcode updates, data visualizations, data analysis, elementary applications logic via alerts and triggers. By enabling the unrestricted access to the devices for the clients, which are even though positioned behind the firewall, a Network address translation (NAT) or mobile network router, connectivity as a service can be attained. Which in turn can collaborte with any device that offers a Transmission control protocol socket. [7] **The following are categories of existing IoT platforms that have been identified**:

**1.** **The Domain-specific platforms** / IoT platforms for facilitating the specific domain situations. Such platforms are often made on the topmost generic M2M connectivity providers. Serving specific purpose to the user for various tasks. Rachio (smart irrigation), nest (home automation), getcleverpet etc. are some examples of such platform.

**2.** **Technology-specific IOT platforms** are the platforms which are accountable for explicit set of devices. These platforms are often looped and are created on the devices with proprietary (having owners) technology. Various examples are Mbed, supporting devices built on Advanced RISC Machine, Zatar, Nest, Cortex-M microcontroller, etc.

**3.** **M2M** connectivity benefactors offering connectivity as a core service and with other limited features which are mostly related to the data analysis. Data acquisition and analysis are the main objective.

**4.** **The Full scale generic IoT middlewares** like ThingWorx deliver wide range of connectivity/connecting services and facilitating the application development based on data acquisition through the devices and altered by the analytical tools/machines. Such type of expansion is conceivable by making use of the unified growth environments, API’s or the linguistic interpreters for easy flow.

**5.** Some other platforms which offer subsidiary services are categorized as important but they don’t facilitate M2M connectivity services and are not placed under IoT platforms in general. But since they do offer functionalities useful for IoT scenarios. Examples are Groove Streams and ifttt, interoperability-as-a service platform offering services.

Cross-platform interoperability and reuse are emerging with the rise of IoT platforms. To reduce conflicts among users/clients more technicality needs to be introduced.  **Conclusions**

Internet of Things (called IoT), related to the concept of "future internet" is an idea where each object (living entity like humans or animals and also non-living entities present in the universe) will become a part of the Internet. Every object which is on network can uniquely be identified, its status and position can be known, is accessible to the network and also services, intelligences to be added to the network is the vision of IoT service. It is a fusion of real world with virtual world of digital technology and impacts our social, personal as well as professional life. IoT is going to change the information world and technology world drastically to make a more comfortable world full of technology for us. Various prototyping computer hardware boards, on chip systems, sensors, radio frequency identification and pervasive networking capabilities are supporting candidates for IoT evolution enhancing its usability.[13]

Although Gartner’s analysis of the emerging technologies positions IoT platforms at the very early phase of development, experiences from this survey show that cloud-based M2M connectivity services offer is well established. Some characteristic market niches are already recognizable, namely, M2M connectivity, data storage and analysis, data visualization, Interoperability-as-a-Service and others. What is clearly missing at this point is IoT ecosystem application building environment. While the objective of this paper was to identify the gap in the current state of art of IoT platforms, comparing to the theoretical foundations and vision of IoT, its motivation was to setup the novel design of IoT platform which core feature will be exactly application development. Based on the survey, following main principles for the development of formal model-driven IoT software execution platform (InoTEP) are defined: - InoTEP is web application for devices in IoT which enables composition and realization of IoT scenarios, by using peer-to-peer approach (multiple InoTEP instances installed on multiple devices, communicating over REST). - InoTEP provides Application-as-a-Service service which will interpret any formal model (RDF/RDFS/OWL ontology) in a runtime and deliver CRUD (create/read/update/delete data) application. - InoTEP enables formal definition of the device’s capability to sense and/or actuate, by using Capabilities ontology. - InoTEP uses RDF as a transport protocol for communication between devices (over REST). - InoTEP tries to match any data received through its own REST interface (external data), with domain and capabilities ontologies. The above listed principles are further used in selection of the enablers of the key components of InoTEP. Application-as-a-Service component will be implemented by using OntoApp system ; W3C Sensor ontology [7] is being extended to develop a Capabilities Ontology; Active Semantic Model approach will be used for a matching engine.

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