# Synopsis of IoT: Internet of Things

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*Abstract*— This paper provides a great insight of the Internet of Things (IoT) with technologies, protocols, and various IoT challenges. This is an era of IoT enabled devices. Today we see a lot of developments in sensors, smart gadgets, home automation which drives through IoT. The current uprising in technologies like internet, mobile, and machine-to-machine (M2M) technologies is the first phase of the IoT. In upcoming years we will see the IoT growth and how it supports the humanity for their betterment of life. This paper starts by providing an architectural view of the IoT. Then an overview of some technical details related to the IoT enabling technologies, hardware, protocols, and applications. Also provided an overview of some of the key IoT challenges presented in the recent literature.

***Key words:*** Internet of things (IoT); Cloud computing; Protocols; Communication

## I. INTRODUCTION

The Internet is a global network connecting millions of computers. Use of the internet is proliferated. To keep up to the user increasing the growth of the internet and the vast ocean of users, something which can bring them all under one roof was needed and so was IoT born. IoT, the term first introduced by Kevin Ashton in 1998, is a future of Internet and ubiquitous computing [1]. IoT a digital revolution where everybody is connected virtually, where the workplace is anywhere and everywhere. IoT technology is a giant network of connected "things" which also includes people. “Things” here can be any equipment apart from regular devices (laptops, pc’s, smartphones etc.) like a toaster/coffee-maker/car/home appliances etc. anything’s which are in daily usage. The relationship will be between people-people, people-things, and things-things. In future machine-to-machine (M2M) communication will provide ease and comfort to human life. IoT involves many technologies including architecture, sensor/identification, coding, transmission, data processing, network, discovery, etc. [16]. Millions and probably billions of ‘smart’ devices are expected to connect to each other and exchange data and information over the internet [7][14]. Actually we have gone from smart place to smart objects in which objects can interact with each other and with people [9]. The basic idea of IoT is to allow autonomous and secure connections and exchanges of data between real world devices and applications [5]. The objects that are not only physical entities, but also digital ones and perform some tasks for humans and the environment. This is why, IoT is not only hardware and software paradigm, but also include interaction and social aspects as well [2]. Ubiquitous computing [6] which was thought as a difficult task has now become reality due to advances in the field of Automatic Identification, Wireless Communication, Distributed Computation process and fast speed of the internet. Individuals will be able to keep track of their belongings from anywhere and anytime and from any network [7]. Internet of Things (IoT) becoming so pervasive [1][4][6] that it is becoming important to integrate it with cloud computing because of the amount of data IoT’s could generate and their requirement to have the privilege of virtual resources utilization and storage capacity, but also, to make it possible to create more usefulness from the data generated by IoT’s and develop smart applications for the users, this IoT and cloud computing integration is referred to as Cloud of Things [3]. The realization of an effective and reliable IoT requires the definition of a complex architecture that takes into account the issues of sensing the real world, transmitting data, and managing the relevant services to build applications [10]. We introduce a novel paradigm of “social network of intelligent objects”, namely the Social Internet of Things (SIoT), based on the notion of social relationships among objects [2].

This paper illustrates the basic information about IoT. Section II will give a brief introduction about the general/ layered architecture, Protocol stack, and applications of IoT. Section III describes Issues, Languages, Software and Hardware used in IoT. Finally, Section IV concludes the paper.

## II. ARCHITECTURE OF IOT

### *A. General/ Layered architecture*

The general architecture or the layered architecture comprised of five layers. These layers are given different names by different authors defined in [6]. Another unique architecture of internet works like mankind nervous system which can see, smell, listen, act etc. “Unit IoT Architecture: Man like Nervous Model” and “Ubiquitous IoT Architecture: Social- Organizational Framework” is described [16].

*1) Layer 1:*

Perception Layer also called as Sensing Layer/Sensor Layer/Device Layer. It includes 2-D bar code labels and readers, RFID tags, camera, GPS, sensors, terminals, and sensor network. Its main task is to identify the object, gathering information [12]. Consist of wireless sensors and actuators.

*2) Layer 2:*

Network Layer: Transport/ Gateway/ Core Layers are other known names. The main function is data integration and analog to digital data conversion. The network layer includes a convergence network of communication and Internet network, network management center, information center and intelligent processing center, etc. [12].

*3) Layer 3:*

Middleware Layer: Also called Processing/Service support/Application support layer. Cloud computing and ubiquitous computing [6] is the primary technology in this layer. [12]. Edge IT systems perform preprocessing of the data before it moves on to the data center or cloud.

*4) Layer 4:*

Application Layer: develops diverse applications of the Internet of Things, such as intelligent transportation, logistics management, identity authentication, location-based service (LBS), and safety, etc. [12]. Data is analyzed, managed, and stored on traditional back-end data center systems.

*5) Layer 5:*

Business Layer: This layer is a manager of the Internet of Things, including managing the applications, the relevant business model, and other business, also do research on a business model and profit model [12].

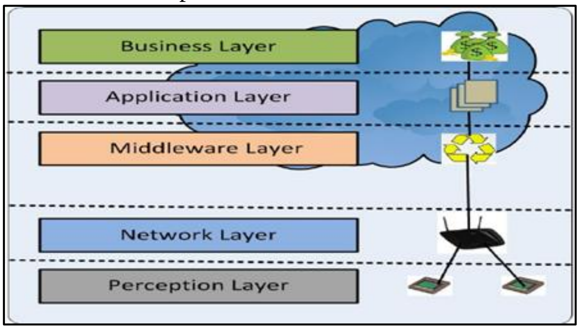


Fig 1: Layered architecture of IoT

## B. Protocol Stack

End-devices usually from Machine to Machine (M2M) networks using various radio technologies, such as ZigBee (based on the IEEE 802.15.4 Standard), Wi-Fi (based on the IEEE 802.11 Standard), 6LowPAN over ZigBee (IPv6 over Low Power Personal Area Networks), or Bluetooth (based on the IEEE 802.15.1) [20].

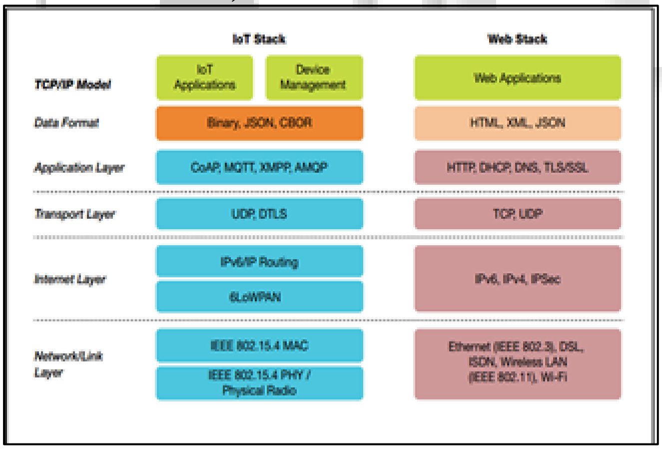


Fig. 2: Protocol stack of IoT is compared to protocol stack of Internet also called as Web stack.

*1) Network/Link Layer:*

IEEE 802.15.4 is a standard for wireless communication that defines the Physical layer (PHY) and Media Access Control (MAC) layers. Focuses on Communication between devices in constrained environment with low resources (memory, power, and bandwidth).

*2) Internet Layer:*

6LowPan allows larger IPv6 packets to flow over 802.15.4 links that support much smaller packet sizes. Frequency range is 2.4GHz and transfer rate is 250 kbps in which it is operated. Fragmentation and Reassembly fragments and reassemble the IPv6 packet and sends it through multiple smaller size packets that can fit in an 802.15.4 frame.We can find the ubiquitous IP address. Header compression compresses IPv6 packet header to reduce packet size.

*3) Transport layer:*

UDP is lighter protocol, faster and smaller header size compared to TCP. Higher levels protocols like CoAP uses UDP than TCP. DTLS (Datagram Transport Layer Security) provides communication privacy. Allows client/server applications to communicate in such a way that it is designed to prevent intruder, interference, or message forgery. IETF seem to encourage the adoption of DTLS [19]. Provides equivalent security guarantees which is based on Transport Layer Security (TLS) protocol.

*4) Application layer:*

CoAP (Constrained Application Protocol) defined by IETF [19] is a specialized Web Transfer Protocol for constrained nodes and constrained networks. RESTful protocol design in which it minimizes the complexity of mapping with HTTP, Low header overhead, parsing complexity, URI and content-type support. MQTT (Message Queue Telemetry Transport) is publish-subscribe based "light weight" messaging protocol for IoT and M2M communication. It is bandwidth efficient, data agnostic, and has continuous session awareness, also minimizes the resource requirements. XMPP (Extensible Messaging and Presence Protocol) considering limited computation and memory resources as well as restricted bandwidth and energy availability XMPP is used for the communication in the proposed system [8]. It holds a wide range of applications which includes instant messaging, presence, multi-party chat, voice/video calls, collaboration, lightweight middleware, content syndication, and generalized routing of XML data. AMQP (Advanced Message Queuing Protocol) an open standard application layer protocol, provides asynchronous publish/subscribe communication with messaging. Its main benefit is store-and-forward feature that secures reliability even after network disruptions [21]. Features are message orientation, queuing, routing, reliability and security.

*5) Data Format:*

CBOR (Concise Binary Object Representation) uses a binary encoding that results in compact message size providing IoT with tiny message sizes. JSON (JavaScript Object Notation) uses text encoding.

Another similar architecture shows the usage of Bluetooth and NFC etc. protocols based on different layers of OSI model. Fig 3 describes these in details.

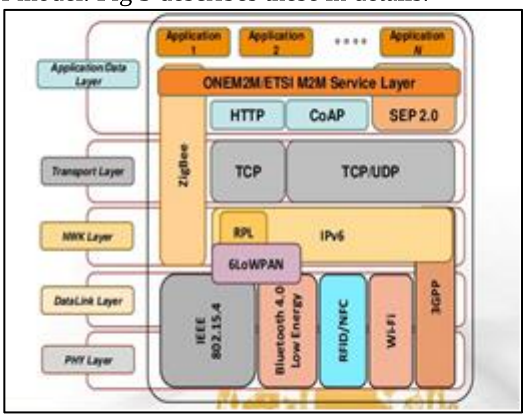


Fig. 3: OSI Layer wise protocol used in architecture of IoT

 

### C. *Applications of IoT*

Smart Homes: These products are promised to save time, energy and money. Owners to modify their home infrastructure for better security and efficient energy management.

*1) Wearables:*

Sensors or devices are highly energy-efficient, ultra-low power, and small-sized. Widely covers fitness, health and entertainment sectors.

*2) Connected cars:*

Mainly focuses on optimization of vehicle's internal functions. Capable of optimizing its own operation, maintenance and comfort of passengers using onboard sensors and internet connectivity.

*3) Smart cities:*

Functions like smart surveillance, traffic management, smart resource management systems, water distribution, urban security and environment monitoring are included. Sensors can detect meter interference issues, general breakdowns and any installation issues in the electricity system.

*4) IoT in agriculture:*

Sensing for soil moisture and nutrients, controlling usage of water and fertilizers. Smart monitoring helps farmers to improve yield, plant more efficient irrigation and make harvest forecasts.

*5) Smart retail:*

Provides an opportunity for retailers to connect with the customers to enhance the in-store experience. Communicating through Smartphones and using Beacon technology can help retailers to aid their consumers in a better way.

*6) Energy Management:*

Collection of data can be done with the help of smart grids in an automated fashion and analyze the behavior of electricity. Acutely and efficiently can able to utilize the energy and can also handle the associated challenges.

*7) Healthcare:*

Consigning people to live healthier life by enacting wearable devices. The collected data will help in personalized analysis of an individual's health and provide suitable strategies to fight illness.

*8) Transportation:*

Automotive IoT initiatives promise to save lives, reduce pollution and commute hassles and simplify transportation for millions around the globe.

*9) Prediction of natural disasters [4]:*

Combination of sensors and their autonomous coordination and simulation will help to predict the occurrence of natural disasters.

*10) Smart Security [4]:*

Better security by providing surveillance of space, tracking people and their assets, equipment maintenance, alarming, privacy.

## III. RESEARCH

### A. *Issues / Challenges in IoT*

Security: Data authentication, data integration, data encryption all off the handling of data is the major concern of security.

*1) Communication:*

How communication between devices will be possible? Naming of devices is very critical problem to solve as there will be billions of devices connected in future.

*2) Performance:*

To calculate the performance of almost innumerable devices is totally impractical to implement.

*3) Optimization:*

Based on maintenance of devices optimization can be calculated but as it is next to impossible to calculate performance it's also issued to check the optimization of devices.

*4) Maintenance:*

To maintain billions of devices needs lots of human efforts will lead to confusion in the end. Taking care of all equipment's and adding their lifespan will lead to minimum cost.

*5) Data Centre Network:*

WAN links are optimized for human interface applications, IoT is expected to hysterically change pattern of transmitting data by its own.

*6) Inter-operability standard:*

Depending on communicating protocols, information exchange between all the interconnected IoT devices is inherently complex. IoT devices needs to lend lot of money and time to create standardized and common protocols for all IoT devices otherwise product deployment will be delayed across different platforms.

*7) Legal Regulatory and Rights:*

Currently no concrete laws are present and issue is whether the current liability laws will extend their arm for devices because there are going to be billions of devices and such devices have complex accountability issues.

*8) Privacy:*

Data of users are collected by devices without their permission and analyze them for purposes only known to the root company. People trust IoT devices because of their social acceptance which leads to collection of their personal data without understanding the future involvement in their personal space.

Languages

*9) C:*

A procedural language, the code is compiled and not interpreted. It is not platform independent. Code reuse is possible, having pointers it is easy to access and modify addresses.

*10) C++:*

A middle-level programming language, having object-oriented, and multidisciplinary programming features with low-level memory manipulation. Characteristics that allowed developers to pick are data hiding, stronger typing/checking, multi-peripheral transparency using classes, templates and initialization list.

*11) Java:*

An object-oriented language, the Access Point (API) provides the modern security standards. Highest levels of networked encryption and authentication which ensure data privacy. Application code cannot be manipulated as all object references are implicit pointers.

*12) JavaScript:*
A scripting language with syntax similar to C. It is good at event-driven applications, allowing every device to listen to various other events and respond to the concerned events. It has a garbage collector which eliminates release of memory.
*13) PHP:*
A number of Raspberry Pi/ Arduino developers are talking about starting up a full LAMP stack with Apache, MySQL, and PHP. Many libraries and serial classes are available in PHP for serial connection to hardware.
*14) Python:*
An interpreted language which can be submitted for runtime compilation. Beneficial as readable with elegant syntax, without any issue with size. Its clean syntax is appropriate for database arrangement. It is user-friendly in more powerful edge devices, gateways, and also the cloud.
*15) GO:*
An open source programming language developed at Google. Combination of compiled language and dynamic language with their benefits that are performance and security. It supports concurrent input, output, and processing on many different channels. Adding explicit hash table type makes it easier to gather and send data to various sensors and actuators
*16) Rust:*
An open source, general-purpose, multi-paradigm, compiled programming language sponsored by Mozilla. It is practical, concurrent and safe language without garbage collector which supports functional and imperative procedural model. Suitable for microcontrollers, network appliances and huge servers with hundreds of cores.
*17) Parasail:*
Parasail stands for Parallel Specification and Implementation Language. It is a compiled, object-oriented language with syntax similar to Java, Python, C#, and Ada. Parallel processing can be implemented with its help, also is highly secure and inherently safe.
*18) B#:*
Very small and efficient embedded control language. The code could be easily ported and reused across multiple hardware platforms. It supports modern object-oriented features like namespaces, abstract and concrete classes, delegates and interfaces and interrupts handlers. Usually used for small applications. Can be embedded with EVM (embedded virtual machine).
*19) Swift:*
Mainly used to build applications for Apple's iOS and macOS devices. If you want your machinery to interact with an iPhone or an iPad, one is going to want to build the app in Swift. Apple wants to make its iOS devices the center of the home network of sensors, so it's been creating libraries and infrastructure that handle much of the work. These libraries are the foundation of its HomeKit platform, which provides support for integrating the data feeds from a network of compatible devices.

## *B. Features of iot*

*1) Peer-to-peer security:*
Certificate-based authentication and TLS 1.2; devices running Android Things or supporting the Cloud IoT Core security requirements can deliver full-stack security.
*2) Meshed services:*
Feed data with Cloud IoT Core, distribute data with Cloud Pub/Sub, apply data transformations with Cloud Dataflow, and store the data in Cloud Storage, Cloud Big-table or Cloud Spanner.
*3) Business process enhancement:*
Integrating Cloud IoT Core with Cloud Functions workflows can improve the operational efficiency as it is making real-time changes to device state.
*4) Ecosystem:*
Enables entities to connect and control IoT devices. Support for devices from hardware partners. Example: Intel and Microchip etc.
*5) Single global system:*
All your devices can be managed as a single global system by connecting devices to Google Cloud over standard protocols likewise MQTT via Protocol Bridge.
*6) Advanced data analytics:*
Analysing data by performing ad hoc survey using Google BigQuery. Visualisation of data is possible via Cloud Data Studio and intelligence of data can be derived by using Cloud Machine Learning.
*7) Managed framework:*
Using Google's Cloud serverless platform infrastructure horizontal scaling can be done instantly without limits of connecting your billions of global devices.

## *C. Hardware*

Sensors/Actuators: Energy is transformed into electrical data by Sensors. They are called eyes and ears of IoT. Actuators transform electrical data into energy and are called muscles of IoT. Types of sensors/actuators are Temperature, Proximity, Pressure, Gas, Heat, Humidity Infra-Red sensors etc.
*1) Processor:*
Processors provide the intelligence behind IoT systems and are often integrated into system-on-a-chip designs. Combine Digital Signal Processor (DSP) and Reduced Instruction Set Computer (RISC) for better outcome. Intel, IBM, Qualcomm, Atmel, ARM, Freescale, Cypress etc. makes IoT processors.
*2) Wireless Sensor Networks (WSN):*
Wireless network of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions. Companies: Libellium, EpiSensor etc.
*3) Transceivers:*
Hardware that enables dual directional communication for data collection and control message delivery. Wireless transceivers sends and receive RF signals over air. IoT transceivers are Avnet, TI, Silicon Labs, Intel, Doodle labs, Nuel, etc.
*4) Power supplies:*
Modern design in power adaptors and AC/DC needs to reduce overall power consumption. IoT power supplies include traditional, thin-film and printed batteries, energy harvesting modules, flexible photovoltaic panels and thermoelectric sources.
*5) Gateway/Hub/Concentrator:*
Device connectivity, protocol translation, data filtering and processing, security, updating, management and more.

*6) Prototyping boards:*

These boards are microcontrollers and microprocessors with chipsets to handle wireless connections. Arduino Uno, Raspberrypi-2, Beagle-Bone black etc.

*7) Storage:*

Edge computing and edge storage model as well as more aggregated cloud storage for billions of devices going to connect IoT. Cloud storage, SQL, FireBase, SenseIoT etc.

*8) Devices/ Wearables:*

Products used by end users that contain IoT technologies. Smart phones, Home appliances, Kaa wearables and applications etc.

### D. Software

*1) API:*

Application Programming Interface is market enabler for IoT. Which allows users to manage devices, enable data transfer between software, and provide access capabilities.

*2) Applications:*

End-users programs which allows user to perform different task. Horizontal applications are standardized e.g., asset tracking, Vertical applications are customized to specific needs e.g., delivery fleet management.

*3) Middleware:*

Integrates various components of IoT application by structuring communication, workflows, and business rules. Companies providing are ProSyst, MundoCore, Gaia, Ubiware, Sensor-Bus etc.

*4) Data Analytics:*

Focuses on development, maintenance and management of complex software systems. Includes real-time or edge computing and batch analysis. Analytics can be behavioral, descriptive, predictive, or prescriptive.

*5) Data Visualization:*

Efficiently data are graphically represented for large data sets. Dashboards, alerts, events, maps, and other tools to present comprehensible data to end users. ThingSpeak, IBM Bluemix, Freeboard etc.

*6) Cloud and Fog Platforms:*

Data management solutions capture, index and store data in traditional database, cloud platforms, and fog systems for future use. Artik cloud, Google cloud IoT, Microsoft Azure IoT suite, IBM Watson IoT, WebNMs, etc.

*7) Security:*

Protect from malicious attacks, intrusion and unauthorized usage of resources. Provides encryption, integrity, access control, and identity protection for individual end-users.

*8) Embedded Operating System:*

Require rapid development tools, standardization, easy maintenance, and porting of applications across a wide variety of hardware platforms. Contiki, Free RTOS, Tiny OS, EmberNet etc.

*9) Visual Programming tools:*

They are modified for programming sensors and embedded computers. Allow users to design on a graphical dataflow-based programming model. Node-RED, Net-lab toolkit, DGLux- 5, Reactive blocks, AT&T Flow desire, WoTkit etc.

### E. Services

The dynamic nature of IoT applications requires IoT to provide reliable and consistent services [17].

*1) System Integration:*

Integration of various machinery is done. Link IoT component subsystems, customize solutions, and confirm the communication with existing operational systems.

*2) Data Management:*

Consultancies help to manage the data in sense-of big data, decide which data to maintain and for how much amount of time period, and also regulates IT issues.

*3) Hardware Development:*

Authorities provide services like specification/details about solutions, designing of product, connectivity setup, and partner identification.

*4) Software Development:*

Supports the development of data analytics, visualization of solutions and data, provides platforms, system security, as well as integration into embedded systems.

*5) Business Strategy:*

Focuses on management of organizational benefits by building business models based on data and information. Example includes go-to-market design and execution, business model development, channel development, and corporate M&A.

*6) Procurement:*

Supports solution selection, ROI analysis, vendor shortlisting, and other areas related to selection and execution of solutions.

*7) Training:*

The program ranges from executive workshops to technical programs intended to upgrade workforces with IoT expertise.

## IV. Conclusion

IoT is an evolving term which is marching towards the advancement of technology with rapid pace. Though having high advantages, it consists of many loopholes yet to be solved. The major problem focuses on security and privacy. Security mainly focuses on data encryption, cryptography, and distinctiveness and intrusion avoidance, etc. types of topics which are rigid and cannot be secured completely. While in privacy it is concerned towards users as their personal details are assembled without their notice. Another problem deals with gateway during installation. Problem of network connectivity, user interface functionalities and internetworking processes, whose solutions are not proposed but can be provisionally solved by BLE (Bluetooth Low Energy) as reported. Conclusively although IoT is rapidly growing technology there are many issues which requires specific solutions for future furtherance before implanting in real world.

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