Big Data on Internet of Things: Applications, Architecture, Technologies, Techniques, and Future Directions

Heba Aly

Information Systems Dept.,
Faculty of Computers and Information,
Mansoura University, Egypt
hebaaly92@gmail.com

Mohammed Elmogy

Information Technology Dept.,
Faculty of Computers and Information,
Mansoura University, Egypt
elmogy@gmail.com

Shereif Barakat

Information Systems Dept.,
Faculty of Computers and Information,
Mansoura University, Egypt
sherifiib@yahoo.com

Abstract

Internet of Things (IoT) is a substantial concept of a new technology generation. It is a vision that permits the sensors or embedded devices to be interconnected over the Internet. The upcoming IoT will be greatly presented by the enormous quantity of heterogeneous networked embedded devices that generate intensively "Big data". Enormously a large amount of data is being collected today by many organizations and in a continuous raise. It turns out to be computationally inefficient to analyze such a massive data. The quantity of the available raw data has been expanding on an exponential scale. In a massive database, the valuable information is hidden. The new developed Big data techniques can handle many challenges that face data analysis and have the ability to extract valuable information.

This survey shows the study of IoT and Big data. The survey discusses Big data on IoT and how it is created. Many IoT existing, future application and a variety of IoT technologies whether wired or wireless are viewed. Challenges and techniques that solve these issues are discussed and the architecture of IoT is observed.

Keywords- Big Data, Internet of Things (IoT), Heterogeneous data, IoT architecture, IoT applications**.**

I. INTRODUCTION

The smart world concepts such as smart devices, smart phones, smart cars, smart homes, smart cities have been adopted for several years. Corresponding to the current opinion of researchers, the five outstanding social research are Internet of Things (IoT), mobile computing (MC), pervasive computing (PC), wireless sensor networks (WSNs), and cyber-physical systems (CPS) [1].

The IoT is a notion that depends on interconnected physical objects It creates a mesh of devices that can able to generate information. Sensors are around us like in cars, buildings, and smartphones that can collect data about our environment [2]. IoT enables us to know things that need replacing, repairing or recalling [3]. These things can contact and interrelate with their neighbors to reach unified goals [4]. Many embedded in “things” collected together and what is referred to as a smart world is created [1].

Li et al. [5] suggested that we can reduce the cost, waste and loss, if we had computers that know everything and can collect data without user help. IoT can cooperate without human interference.

The evolution of the IoT relies on technical innovations in many fields, from wireless sensors to Nanotechnology. These innovations allow ideas to turns into specific products or applications. Existing research on IoT emphasizes on how to enable broad objects to see, hear, and smell the physical world by themselves. It makes them connected to share the observations [6].

The vast existence of varieties of things, such as sensors, actuators, and mobile phones, result in the great presence of the IoT notion. Behind all expectations, IoT enhances the living standards. The advantages related to link sensor data or networking between sensors is widely deployed in many fields. It contains environmental monitoring, disaster management, human motions, health, smart cities, and understanding social phenomenon [7].

IoT generates numerous amount of data therefore called "Big data," that provides advanced analytic techniques and offers a vision that makes machine usage easier and efficient. The Big data analysis is required to take advantage of its potential for high-level modeling and knowledge engineering. The possibility of the data flow from physical resources to future Internet facilities is what we need to an analysis by using Big data analytic techniques. The Big data challenge is how to understand the interaction between human and smart objects. The basis of the Internet was human to human interaction when the human determines the content to be used by another human, but with the IoT the objects determine the content. Therefore, the impact on our lives is an open issue that needs understanding how IoT plays an important role in a smart environment and smart world [8].

The rest of this paper is organized as follows. Section II introduces creating knowledge and Big data. Section III discusses different types of applications of IoT. Section VI shows the technologies of IoT. Section V discusses techniques and methodologies. Section VI shows IoT Architecture. Section VII explains the previously related work. Finally, challenges and future Directions of IoT are discussed.

II. Creating Knowledge and Big Data

The notion of the Big data is related to the computer science since the earliest computing days. The data volume that goes beyond the processing capacity of the usual database and cannot be handled by traditional database techniques is called, "Big data." However, if we have a large amount of data, it requires different approaches like techniques, tools, and architecture with the aim to solve new problems or old problem in better ways [9].

A report released by Gartner [10] says entering into a connected devices world; IoT is estimated to accelerate and reach to 26 billion connected devices by 2020.

It has been observed four main Big data challenges (the four Vs.):

- Expanding data volume.
- Expanding velocity of data as in/out and change of data.
- Expanding variety of data types and structures.
- Expanding data veracity.

The fifth V is suggested as the value [11], which is the contribution of Big data and able to make decisions. IoT will rapidly increase the volume, variety, and velocity of data. Therefore, enterprises begin to hold on current Big data challenges. As usual, solving the problems of data storage, integration, and IoT analytics is the responsibility of IT.

In IoT, a huge amount of raw data is collected on an ongoing basis. Therefore, it is essential to develop new techniques able to transform raw data into valuable knowledge. For instance, in the medical domain, significant actions done by human- like eating, drinking, breathing, and signs can be detected by transforming meaningful sensor raw streams to it. The collected data will be intensive. It is expected to be an enormous amount of sensor data streams. These streams of data may be used in different ways for different purposes. Therefore, the resources of data and how it was processed must be known, and the privacy and security must be provided [1]. The coming IoT will be greatly presented by the enormous quantity of heterogeneous networked embedded devices that produce intensive or "Big data". The collected Big data may not have any value unless analyzing, interpretation, and understanding. The data mining techniques are the mainly recommended methods to be used in extracting knowledge from raw data [1], [6].

III. Applications of IoT

The IoT is not a compatible theory. It is an application technology that is useful to our life. The value of IoT comes from many applications. Applying solutions for these applications will be the primary principle invention engine. There exist some successful applications already developed in different fields like transportation, smart environments domain, health care domain, food sustainability, and futuristic applications [5], [12].

A. *Transportation*

1. Smart parking

The smart parking offers solutions for management of parking that can help drivers to save time and fuel. By providing accurate information about vehicles parking spaces, it will be useful for making traffic flow better and reduce traffic jam [13].

2. 3D Assisted driving

Vehicles like cars, buses and trains that are fitted with sensors can give useful information to the driver to save better navigation and safety. By using 3D assisted driving, the drivers can determine the correct path based on prior knowledge about traffic jam and accidents[13].

B. Smart environments domain

1. Smart water supply

Water supply in smart cities should be tracked to guarantee that the water amount is sufficient for life needs. The smart cities can be able to detect water loss problem before it occurs, and so it can significantly save on the budget. It helps the smart cities to detect the water leak sites and identify reform priority to prevent much amount of water from loss [13].

2. Smart homes and offices

Sensors, actuators, and controllers can be added to several home and office devices as a fan, fridge, washing machine, air conditioner, and microwave. For example in Turkey, they apply an application for a home that is a solution for many problems. This application can monitor home remotely, detect fires, protect home from thefts, and control devices as a heater and air conditioners from remote devices as a tablet, computer or phone [13], [14].

C. Healthcare domain

1. Health tracking

Radio Frequency Identification (RFID) technology is useful for monitor person's health. The patient's medical data can be measured by sensing devices and sent remotely to his to pursue his health [13],[15]. IoT applications involve connecting the sensor to a person that can track the user's heart rate or pressure of blood continuously, for investigation via software or mobile applications [16].

2. Pharmaceutical products

Smart pharmacy is a perfect application that helps easy accesses to remedy. Sensors attached devices can monitor the state of the drugs. In the case of finding expired drugs, it will prevent it from accesses to the patient. For instance, smart pharmaceuticals is a South African enterprise that offers a set of high features, low-cost pharmaceuticals to pharmacies, doctors, and other health-care societies [13], [17].

D. Food sustainability

There are several phases that food crosses from it before putting into the fridge. These stages are production, harvesting, transportation, and distribution. The food can be saved from damage by using sensors that able to monitor the status of the food and track temperature, humidity, and light to protect food. Effective food monitoring helps in plant protection from damage and control water amount [13].

E. Futuristic applications domain

The applications mentioned in the previous sections are realistic as they either have been already deployed or can be implemented in a short or medium period since the required technologies are already available. The next mentioned applications are not implemented; it will apply in the future[4].

1. Robot Taxi

Smart robot taxis in smart cities can treat with each other and provide services when requested by people. Robot taxis can treat easily with traffic congestion. It can move without the drive. It can avoid accident occurring. Using sensors and GPS, it can detect the position of people who request the robot taxi. In the case of stopping when sensors notified that actuators set off recharging batteries, it can make simple maintenance and clean the car [4].

2. City information model

The City Information Model (CIM) is depending on the notion that suggests all buildings is tracked by the government and allowed to the third party. Smart economy, smart people, smart devices, smart mobility, smart governance, etc. can simply interconnect with each other. Smart cities models should be integrated to improve performance and efficiency of the system [4].

IV. TECHNOLOGIES

The IoT involves devices to acquire technology from the physical world and transform them into data. Technologies in IoT can be divided into data acquisition and network acquisition technologies.

- Data Acquisition Technologies

Because of the fast growth in computer hardware, software, the Internet, and sensors, the mobile communications have developed to enhance services. Additionally, they have extended into new application areas, with better services and features with minor costs.

a) Two-dimensional code

It is a barcode that represent the data that the machine can read it. The one-dimensional code can read characters and numbers only and cannot read Chinese letters and images. The two- dimensional code was evolved to solve the one-dimensional code issues. The two-dimensional code handles black and white pixels that are represented on a 2D plane to save information. In the two-dimensional code, (0) expresses white, and (1) expresses black. The advantage of the two-dimensional code is the ability to express a variety of information as sounds, images, texts, and numbers. The Two-dimensional bar code was evolved by algorithms. The usual structure of images is monochrome BMP that result in the minimum volume in bytes [18].

b) RFID Technology

RFID technology can read remote source at a long distance. The identification code related to a tag so that, the resulting tag code can be sent to one or more readers. RFID involves of data communication between devices' readers and RFID tags, and it is a standard technology that can be used by many constructors. Therefore, accurate standards occur to confirm appropriate implementation. These standards are the EPCGlobal UHF v.1.2.0 and ISO 18000-6C. Many bank cards and roll tags are using passive tags [18],[19]. Communications can be created by active tags that have onboard battery provision. The main application of active tags is monitoring cargo in the part container. By comparing RFID with two- dimensional barcodes, the main advantage of RFID than two- dimensional barcodes is the ability of non-contact operation without user intervention [20].

c) Sensor

We can use sensors to describe objects or devices. There are varieties of sensor types as active pixel sensors, digital sensors, and biosensors.

- Active pixel sensor (APS) is an image sensor involving of an integrated circuit including a collection of pixel sensors; each pixel has a photo indicator and an operating amplifier. An essential benefit of CMOS APS architecture is its high efficiency [21].
- Digital sensors a digital sensor that is an automated or electrochemical sensor, wherever conversion and transmission of data are completed digitally. The requirement of digital measurement and wireless transmission manage remote PC-based sensor diagnostics, tracking, and analysis. Applying the massive operating capacity, result in hard analog electronics requirements enhancement [22].
- The biosensor is an analytical device used for determining analytic that include biological components and physicochemical detector. Biosensors depend on screen printed, so it is used for a large extent construction. Despite the biosensors composed from bio-components, many challenges face biosensors as long response time, short constancy, and poor generation [23].

- Network Acquisition Technologies

WSN is a principle network that permits things to form communication with each other. Wireless radio interfaces have small varieties, and hence intermediate nodes are used for the spread of data. One, several or all nodes in the sensor network can behave as gateways to the Internet. The key benefit of WSN is that the probability of peer-to-peer communications among the nodes exists. The variability of short scope access networks is merged with a wide range network like the Internet to design an enormous intelligence network. Therefore, the things are connected to each other in their small network, and the small network can be connected to large networks to complete the IoT [18], [19].

a) Zigbee

Zigbee is a wireless network technology constructed for little sensor degree. This protocol includes the network layer, the infrastructure layer, and the application layer. These layers are defined in its concepts [18].

b) Z-Wave

Z-Wave is a wireless interconnection technology that authorizes spread from a management entity to one or more entities in the network. It consists in its architecture of the network, infrastructure, and application layers[18].

c) 6LoWPAN

Low-power Wireless Personal Area Networks (LoWPANs) are wireless networks that constituted of a vast quantity of low-cost devices. They are measured with similar wireless networks. LoWPAN includes challenges as small packet sizes, low bandwidth, low power, large volumes of devices, battery groove, and unreliability from radio connectivity challenges. When they are merged with the Internet Protocol (IP), the constraints of LoWPAN are suited. So, there is 6LoWPAN [18].

V. TECHNIQUES AND METHODOLOGIES

There are several techniques and tools for solving many IoT data management challenges like Big data, cloud computing, semantic sensor web, data fusion techniques, and middleware.

- Big Data Analytics and Tools

There are many techniques or methodologies that can solve IoT data processing and analytics issues in many concepts, fig.1 showed the Apache Hadoop ecosystem.

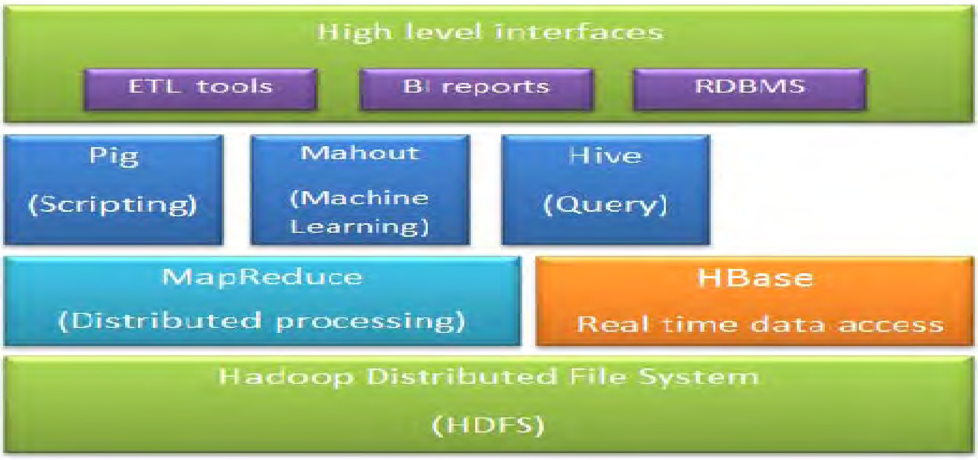

Figure. 1: Apache Hadoop ecosystem.

a) Hadoop:

Hadoop is an open source mission that managed by the Apache Software Foundation. Big data can be collected and handled by Hadoop. Hadoop is proposed to parallelize data processing through computing nodes to hurry computations and hide latency. There are two main components for Hadoop: Hadoop Distributed File System (HDFS) and Map Reduce engine. HDFS stores enormous data constantly set and reproduce it to the user application at high bandwidth. MapReduce is a framework that is used for processing massive data sets in a distributed fashion through numerous machines [24].

b) Map Reduce:

MapReduce was constructed as a broad programming paradigm. Some of the original employments offered all the key needs of parallel execution, fault tolerance, load balancing, and data manipulation. The Map Reduce named with this name because it includes two abilities from existing functional computer languages: map and reduce. The MapReduce framework gathers all sets with the common key from all records and joins them together. Therefore, it acquires forming one group for each one of the different produced keys. MapReduce is one of the new technologies, but it is just an algorithm, a technique for how to fit all the data. To acquire the best from MapReduce, we need more than just an algorithm. We need a collection of products and technologies created to manage the challenges of Big data [24], [25].

c) HBase:

HBase is a database model inside the Hadoop framework that looks like the original system of Big Table. The HBase has a column that operates as the key and is the only index that can be used to get back the rows. The data in HBase is also saved as (key, value) sets, where the subject in the non-key columns can be represented by the values [19].

d) Hive:

The already deployed tools for data warehousing are not able to be suitable especially in the situation wherever, data is accessible everywhere; they are costly and often privately-operated. Such as the notion like MapReduce is there, it requests for the ability to write job procedures. Map Reduce jobs are difficult to track the characteristics of reusable code as some jobs are business particular some of the time. Hive may be thought as the necessary portion of Hadoop system and views at the top that principally is the organization for the data warehouse. Hive cannot treat with applications and transactions of the real time those are achieved online. The motivation behind it is a complicated technique [26].

e) Pig:

The Pig implementation designed within the Hadoop framework to offer additional database as functionality. A table in Pig is a group of tuples, and every field is a value or a set of tuples. So, this framework permits for nested tables, which is a great notion. Pig also provides a scripting language called PigLatin that offers all the common concepts of SQL, such as projections, joins, sorting, grouping. PigLatin differs from SQL as scripts are procedural and are simple for programmers to be understood. The PigLatin language offers a higher extraction level to the MapReduce framework, as a query in PigLatin may be converted into a sequence of MapReduce tasks [19].

f) Mahout:

Mahout is mainly built on an Apache open-source library which able to be scaled and managed for the massive volume of data. These segments rely on three significant machine learning missions that Mahout presently operates.

- Collaborative filtering
- Clustering
- Categorization/Classification [26].

g) NoSQL:

It is an abbreviation to Not only SQL, and the most usual notion for non-relational databases. These databases are appealed to operate better than SQL databases. Various types of NoSQL databases, which are key-value pair document, column-oriented, and graph databases, that permit programmers to display the data suitable to the structure of their used applications. Because of the growth of the Internet usability and the accessibility of low-cost storage, a massive quantity of structured, semi-structured and unstructured data are acquired and saved for different types of applications. This data is usually denoted to as Big data. Google, Facebook, Amazon, and several other enterprises use NoSQL databases [27], [28].

- Cloud Computing

Google's cloud computing is the most used cloud computing. Data storage technology is the Google File System(GFS). Data management technology is the BigTable, in addition to the Map-Reduce that discussed in the previous section as a programming model, used in cloud computing.

a) GFS:

GFS is a distributed file system established by Google Inc. GFS is enhanced for Google's main data storage and usage requirements that can produce massive quantities of data that requires recalling. GFS has many purposes, such as performance, scalability, reliability, and availability of the distributed file system manipulated by application workloads and technological environment of Google[29].

b) BigTable :

A Big Table development is initiated in 2004 and is now used by a much of Google applications, such as MapReduce. It is often used for producing and altering data stored in BigTable, Google Reader, Google Maps, Google Book Search, Google Earth, Blogger.com, Google Code hosting, Orkut, YouTube, and Gmail. Google's motivation for evolving its specific database contain scalability, and better control of performance features. BigTable is augmented for data read processes, by distributed data storage management model, which is based on column storage to enhance data retrieving effectiveness. The main components of BigTable are a row, column, record tablet, and timestamp. Amongst them, there cord tablet is a link to the set of row [30].

- Semantic Sensor Web

The quantity of existing sensors will be enormous, and the gathered data will be intensive. If we have the ability to put the collections of data into a homogeneous and heterogeneous form, then the interoperability problems of understanding the data will rely on the semantic technologies to process the data [31]. There are many aspects of semantic sensor Web as:

Ontology

Ontology is the core of any semantic technology as semantic sensor Web. It is a tool for knowledge allocations and usage. Semantic Ontologies can be divided into some formats as OWL and RDF [19], [27].

- OWL:

OWL stands for Web Ontology Language. It defines discrete data substitution format. The great benefit of this ontology format is that there is no limitation to represent constraints as domain or range constraints [27].

- RDF:

RDF is an abbreviation for description research framework. It is a research description language. This language determines the way that resources can interconnect with each other and perform interpretations [19].

- Data Fusion

It is a multidisciplinary extent that includes numerous fields, and it is difficult to launch a clear and precise classification. The developed methods and techniques can be divided as said by the following principles:

- According to the associations between the input data sources. These associations can be described as: (a) complementary, (b) redundant, or (c) cooperative data.
- According to the input/output data types and their nature.
- According to an abstraction level of the employed data:
    (a) raw measurement, (b) signals, and (c) characteristics or decisions.
- According to the different data fusion levels stated by the JDL.
- According to the architecture type: (a) centralized, (b) decentralized, or (c) distributed [32].

• Middleware

Middleware is an integration between applications and services operating on heterogeneous computing and communication devices. Many middlewares are listed below [33]:

- Message- Oriented Middleware (MOM/ MQ/ JMS/ ESB)
- Transaction Middleware (TPM/ Tuxedo)
- Peer- to- Peer Middleware (JXTA)
- Mobile Computing Middleware (OSA/ Parlay/ JAIN/ OMA)
- Grid Middleware (PVM/ MPI/ Schedulers)
- RFID Edge Middleware (OATSystems, Sybase, Oracle, Tibco, SeeBeyond, IBM, SAP, Connectera, GlobeRanger, Manhattan Associates)
- Real- time CORBA Middleware (Real- time CORBA)
- Process- Oriented Middleware (WebMethods, SeeBeyond, Tibco, IBM, SAP, Oracle)

In the subsequent subsections, some IoT middleware proposals are listed:

1. UBIWARE

It is an agent-based middleware that characterizes each source as a software agent. An agent is responsible for supervising the state of the source, and supporting the interoperation of the source with other elements. The core notions of UBIWARE is to permit automatic discovery, orchestration, choreography, invocation and execution of different Business Intelligence services [34].

2. Hydra

The Hydra middleware involves of a service-oriented architecture. It depends on Web services to support the resource discovery, description, and access that relies on XML and Web protocols. Hydra network uses a proxy to connect the restricted devices to it. The two principle tasks achieved by Hydra developers are (i) integrating non-Hydra devices and (ii) connecting Hydra-enabled devices to a network [34].

3. Link Smart Middleware

The Link Smart middleware deployed in the Hydra project permits the integration of heterogeneous physical devices into applications via a Web service interface for directing any physical device irrespective of its network technology, such as Bluetooth, RF, ZigBee, RFID, and Wi-Fi. Link Smart relies on a semantic model-driven architecture and permits the use of devices as services both by embedding services in devices and by proxy services for devices. The semantic description of devices relies on ontologies using OWL, OWL-s and SAWSDL [34].

4. Open IoT

The Open IoT project offers an open-source middleware platform. It allows the development of IoT applications rendering to a utility cloud computing delivery model. Open IoT role is to recognize the idea of on request access to IoT services obtained over clouds of Internet-connected objects, the called sensing as a service, offering a "cloud-of-things" [34].

VI. IoT Architecture

The architecture of IoT has two perspectives. The first is the old perspective that considers the IoT architecture as three layers. The second is the new perspective that considers IoT as five layers.

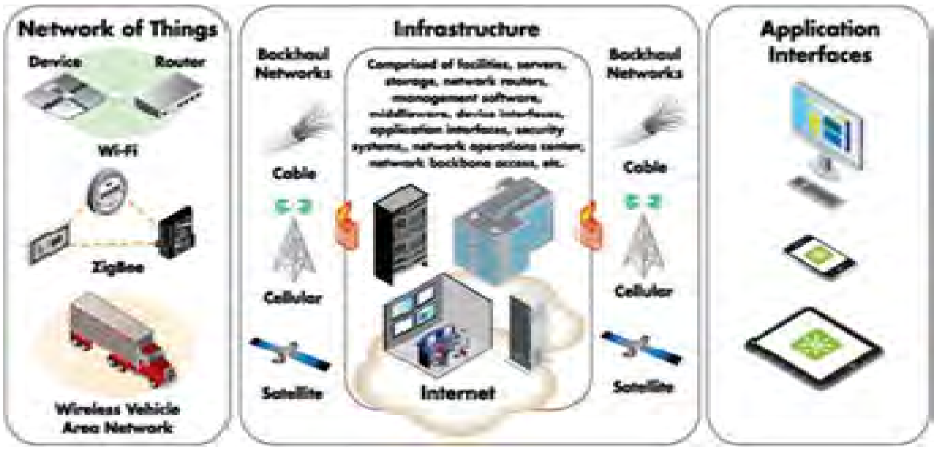

Figure. 2: The three layers architecture of the IoT [35].

a) The Three Layers Architecture

Fig. 2 shows the three layer architecture listed as follows:

1. Network Layer:

The network layer may furthermore be termed as "Transmission Layer". This layer can transfer streaming sensor data from physical devices to the next layer. It can transmit the data to application devices via information processing system or infrastructure layer. The transmission channel may by wired or wireless, and the used technology can be 3G, Wi-Fi, Bluetooth, ZigBee, 6lowpan, etc. based on the sensor objects [36]. The network layer contains a merging network of communication and Internet network, information center, network management center, and intelligent processing center, etc. [37].

2. Infrastructure Layer:

There are several elements of infrastructure that may result in many problems for users. Infrastructure should be promoted for services that are simply acceptable and to the expansion the velocity to the marketplace. Infrastructure commonly denotes to Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) [35].

3. Application Layer:

This prototypical layer defined the construction of IoT from the technical level. It is practical at the early phase of development. The application layer is the great conjunction of IoT and industry technology, merged with industry requirements to recognize the industry, like person's social separation of work, and the formation of the human economy [37].

The previous model is not exactly appropriate for IoT. It has some similar characteristics in mutual. So through the technology architecture of the internet and the logical structure of Telecommunications Management Network, and merged with the specific aspects of the IoT, new architecture of IoT is created. This architecture would better explain the characteristics of IoT. It divided IoT into five layers, which are the Business Layer, the application layer, the Middleware Layer, the Network Layer, and the Perception Layer. As shown in Fig. 3:

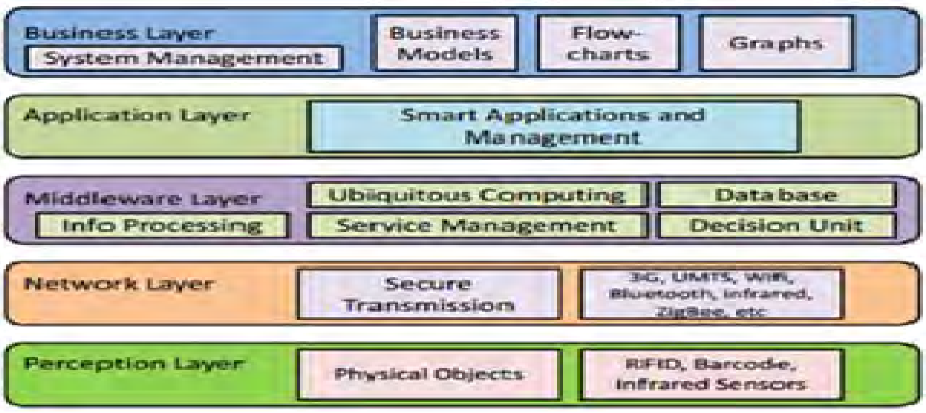

Figure. 3: The new IoT architecture (five layers) [36].

b) The Five Layers Architecture

1. Perception Layer

It is also called device layer. It composed of physical objects and sensor devices. It is responsible for gathering physical object features such as humidity, motion, temperature, location, and acceleration. It is done by varieties of sensors like RFID, 2D barcode, and another sensor type. The collected data is transmitted from perception layer to network layer. The main purpose of perception layer is transforming gathered data to digital signals [36], [37].

2. Network Layer

The network layer may be called as "transport layer." The medium of data transition may be wired or wireless, and the using technology can be Wi-Fi, 3G, Zig-Bee, Z-Wave, etc. The basic task of this layer is transportation. It transports data from the network layer to the middleware layer [36].

3. Middleware Layer

This layer also termed as "Processing Layer". Middleware layer is responsible for storing, analyzing, and processing the information of objects that received from the network layer and linked to the database. It can make computations and take decisions depending on the results signals [36], [37].

4. Application Layer

This layer offered inclusive management of application that relies on the objects information that processed in the middleware layer. The implemented application of IoT may be transportation, logistics, smart health, smart home, smart city, etc. [36].

5. Business Layer

Business layer likes a manager of IoT. The management includes applications, relevant system model, and services. Technology success relies on technology priority as well as innovation of business model. The purpose of this layer is to determine the future actions and business strategies signals [36], [37].

VII. RELATED WORK

Big data in IoT is considered as an important research topic and would be divided as follows:

1. Big Data Techniques for IoT

Many researchers that use Big data techniques to solve some IoT challenges. For example, Mesiti and Valtolina [38] proposed a framework that able to gather data from different sources with different forms like JSON, XML, textual, and data streaming from sensors. The data collections lead the database to be unstructured and require data integration. As the world moves to develop Big data analysis techniques, they reached a solution that can be load data from heterogeneous sensors then integrate that heterogeneous sensor data using NoSQL systems. Finally, they designed a user-friendly load system for NoSQL systems by determining a plan to select appropriate NoSQL system that allow the conceptual schema to be deployed. They are continuing operations of handling schemes, and they intend to begin the implementation. In this paper, they did not observe a solution in the case of newly added data that ensure system availability and stability.

Ding et al. [39] offered a general statistical database cluster mechanism for Big data analysis in the IoT (IoT-statistic DB). One of the major problems that face IoT is how to transform sensor data into knowledge. Statistical analysis on sensor sampling data is one of the most important procedures in IoT systems. Four statistical analyzing methods were offered which, include the Euclidean-based spatial aggregation, the Network-based spatial aggregation, the Euclidean-based parameter aggregation, and the Network-based parameter aggregation. The parallel processing techniques for the statistical queries are proposed, so that multiple servers can apply the statistical analysis in parallel and the performance can be enriched. They intend to discuss event detections and data mining techniques depending on the statistical analysis of IoT. It is not marked how to treat with anomaly presence.

Hayes and Capretz [40] proposed an algorithm for anomaly detection in Big Sensor Data. In particular, an algorithm of contextual anomaly detection is suggested to progress a point anomaly detection algorithm. In this paper, they planned to create a contextual anomaly detection technique for the usage in sensor networks of streams. The technique uses a usual content anomaly detection algorithm for anomaly detection. In addition to this technique, they added a post-processing context-aware anomaly detection algorithm based on a multivariate clustering algorithm. The authors proposed a MapReduce methodology to outline the sensor profiles used in the context detector. They suggested additional modules added to this work such as, for example, a semantic anomaly detector. The anomaly detection abilities of the proposed algorithm should be enhanced.

Ding et al. [6] suggested Big data analytics tools as massive heterogeneous data analytics, nonlinear, high-dimensional, and distributed and parallel data processing, respectively. For IoT applications, the obtained massive sensing data can be in various features, which is much more challenged. The practical requires suggesting an efficient developing of algorithms for Big data analytics, which are grouped into four modules:

nonlinear data processing, heterogeneous data processing, high dimensional data processing, and distributed and parallel data processing. They need to enable smart source provision, automatic network process, and intelligent service provisioning.

Fazio et al. [41] designed framework for the high heterogeneity data. They presented a new architecture able to make a dual abstraction of complex sensing infrastructures along with data they collect. There are varieties of heterogeneous smart sensors that interact with each other. Thus, integration is essential. The benefit of this work is to provide a service at a worldwide level that is scalable and flexible. The deployment of this framework depends on the Bayesian algorithm in addition to Contiki Operating System. They aim to deploy advanced applications for aggregation and filtering of data. Bayesian is a less performance algorithm, so the algorithm that has been used should be enhanced.

Elnahrawy and Nath [42] proposed a framework for cleaning and inquiring noisy sensors. They reduce the uncertainty related to the random noise results from sensors. So they proposed a Bayesian approach for solving this problem in an on-line form. This concept combines prior knowledge of the sensor reading, the noise features of this sensor, and the detected noise reading to get a more precise estimation of the interpretation. This cleaning phase can be done in both sensor stage and base location. Many algorithms for resolving traditional database queries are presented depending on indecision models and statistical method. They aim to propose a framework that can shoulder new pending data. There are several frequent sensor data is needed to be reduced.

2. Middleware Architecture for IoT

Some researchers depend on Middleware architecture on solving IoT problems. For example, Cyril et al. [2] proposed software architecture that able to support Big data research work that used a significant amount of datasets that came from physical sensors. These datasets come from SMARTCAMPUS project. Their architecture can solve real life requirements extracted from the SMARTCAMPUS project. As a consequence, the work done in this architecture depended on data gathering and storage, i.e. the critical path of any Big data collection platform by using middleware architecture. They planned to develop software that enables each user to create its applications. Due to this architecture, if they added a new data the system software can be down, so the system scalability should be enhanced.

Peng et al. [43] worked with a large amount of sensor data. They used a new data processing model that is a message oriented middleware data processing model depend on data analysis, transition, and storage. By applying the middleware architecture, the entire message can be written and sent. The devices in this model separated to devices for tracking data and devices for computing or analyzing data. In this paper despite a centralized approach has many advantages, it may act as single point of failure.

3. Cloud Computing for IoT

Some researchers offer cloud computing as a solution to IoT problems. For example, Ding et al. [44] analyzed the challenges in IOT data management. In this paper, they worked on massive and heterogeneous data problem. They designed solution for these problems which called Sea Cloud Data management framework to face these challenges. Massive sampling data from sensors can be managed by RDB-KV cloud management model that merge the benefits of relational databases and key-value store. They aim to develop new techniques for data mining, OLAP, and analyzing intensive data. It is not discernible in the presence of mind the spatial-temporal data.

Liancheng and Jiao [45] designed Map Reduce model of cloud computing. In the mechanism of Map Reduce, they merged the architecture characteristics and key technology of IoT, conducted distributed mining on data and information in the IoT world, estimated the representation of distributed data stream mining. In the traditional manner for mining useful data from intensive data produced by IoT, analyzes shortages of the traditional Apriori algorithm that has a lower mining efficiency and take up mass space in memory. The mining method of massive data in the IoT comprises data stream analysis, classification, clustering analysis based on path, frequent pattern, sequence pattern analysis, and outlier analysis, etc. They aimed to propose a framework for processing Big data with a low charge and apply privacy of data. The proposed framework has a low efficiency, so it needs to be improved.

Sowe et al. [7] proposed a solution to massive heterogeneous sensor data problem, which required making integration between different forms of data. This problem is an integrated IoT architecture that incorporates a Service-Controlled Networking (SCN) as a key middleware to manage heterogeneous data gathered from sensors on a Big data cloud platform. This model applied to gather and save data and control IoT societies, to permit the user to explore, discover, and utilize the sensor data. They aim to use User Defined Harvester (UDH) technologies in addition to SCN to increase the involved sensing. In this paper, mobile sensing data is not available. They should implement the framework that can treat with these sensing data.

Mozumdar et al. [46] implemented BigCO: a Big data correlation orchestrator for IoT. This orchestrator is executed in a micro cloud server that aim at centralized control in addition to distributed wireless sensor device. They showed how data could be investigated by the 3D display and offer a streaming data compression.

Applying their needed compression algorithm, they have reached as high as 99.86% compression of sensor data. Embedded sensor networks can generate an extreme amount of data. Data must be gathered and sent to a remote cloud server. Their study ensures that gathering data from several sensors can result in gigabytes of data in a week. Because of wireless sensors have a restricted storage size; they need to stop generating new data to old data is offloaded. They propose multi-orchestration that able to control multicast and unicast data reception. This architecture has low availability and disaster retrieval for massive data.

4. Data Fusion for IoT

Many research works focus on data fusion in solving IoT problems. For example, Zhou et al. [47] suggested fusion by using partitioning. In IoT, the intensive volume of data (Big data) is gathered from different sources that result in data heterogeneously. This requires data integration and fusion. The primary notion includes the partitioning of attributes, for instance, a Big data set with intensive volume can be transformed into defined number of quite smaller subdividing of data that can be simply succeeded. Then the visible substances of all data subsets in rough set theory are calculated to obtain their essential attribute sets. Finally, the fusion results are obtained from attribute reduction and rule extraction methods. They intend to make a model to list the better efficiency and effectiveness of the suggested algorithm. The performance of this algorithm should be improved to be able to satisfy a large amount of data.

VIII. CHALLENGES AND FUTURE DIRECTIONS OF IOT

The IoT offers several new prospects to the industry and end user in many application fields. The IoT needs theory, technology, architecture, and standards that join the virtual world and the real physical world in a merged outline. Some key challenges are listed in the following subsections.

1) Architecture Challenge:

IoT covers an extensive variety of technologies. IoT includes a cumulative number of smart interconnected devices and sensors such as cameras, biometric, physical, and chemical sensors. They are often nonintrusive, visible, and hidden. The devices are connected in a wireless or ad hoc manner as the communication may occur at any time and the facilities turn into mobile dependent and more complex. In IoT, data collected from different resources so it will be difficult to integrate these heterogeneous data. The solution is collecting data from various sources and determining the common characteristics between them to explain data and find the associations for support decision-making. The existence of heterogeneous reference architectures in IoT is important. IoT architecture must be reliable and elastic to suit all cases as RFID, Tags, intelligent devices, and smart hardware and software solutions [48].

2) Environment Innovation Challenge:

IoT is a complicated network that might be achieved by some sponsors, where services should be openly produced. Therefore, new services or applications should be supported without resulting loads for the market accesses or other operation blocks. So, the cross-domain systems supporting innovation is still deficient [5].

3) Technical Challenge:

There are several technical challenges as Heterogeneous architecture in the network technologies and applications. IoT contains different types of networks that are not easy to integrate them. The cost of communication technology should be small and connections must be reliable. Defining the form of suitable security and privacy solution is a complicated process. Activation of automated services stills a challenge [5], [48].

4) Hardware Challenge:

Smart devices with enhanced inter-device communication will lead to smart systems with high degrees of intelligence. There are five challenges that face hardware in IoT, cost, electricity and energy, environment-related problems, connectivity, and maintenance. IoT connections depend on wireless that somewhat low cost and low size. Hardware devices must be designed to use the smallest amount of power and longtime battery. The outer environment may affect the hardware efficiency as pollution, humidity, and heating. The connection must be reliable and flexible and not depend only on wireless, the Internet or data should be allowed. It is expensive to maintain damages in sensing devices, so maintenance and support should be local [48], [49].

5) Privacy and Security Challenge:

Problems of security and privacy in IoT become more obvious than a traditional network. Despite there exist a great number of researchers in security and privacy, there is a continuous demand for security protection and confidential privacy of data. Todays, user's information has an extensive privacy, so privacy protection is a significant issue. There are many issues should be considered in IoT and need new technologies to be solved as the definition of privacy and security, trust mechanism, the privacy of common and user data, and security of services and applications. Security architectures that are designed now may not be suited for IoT systems. Approval of new technologies and services depend on trustfulness of information and protection of data and its privacy [5], [48].

6) Standard Challenge:

Standards make an important task in developing IoT. A standard is important to permit easy and equal access and use to all actors. Standard and proposal developments will encourage the development of IoT infrastructures and applications, services and devices. Standardization permits product and services to do the best. The standardization will be difficult because of vast speed in IoT. Protocols and multi-parities can develop standardization. It should be open. In addition, the standard development process should be open to all actors and the resulting standard should be public and free [5], [48].

7) Business Challenge:

For advanced application, it is easy to convert business model and application scenario into technical requirements. So the developers do not want to waste time on business aspects. In IoT, there exist many uncertainties in business models and application scenarios. The problem is that there is no solution of business technology algorithm to suit all. The IoT is a prevention to traditional business model. In the first step in business model development in IoT, business requirements must begin with reducing system failure [48].

8) Development Strategies:

IoT has been developed in different areas and states in three main plans and chances financing approach. In the states such as the US, the short-term yield to finance drive of the progress of smart energy, smart cities, and RFIDs. Through the social media network, some services, and applications, such as location-based services, augmented reality, and smartphones, are leading to the development of IoT. Although it is not yet obvious which strategy is more effective, all of them can encourage IoT and its applications. However, how to determine the efforts of available resources at a planned level acquires another challenge [5].

9) Data Processing Challenges:

Data processing is an essential property in the IoT. By observing the interconnecting devices and objects that exchange different forms of data, the resulting gathered data has an intensive volume [50]. The storage data centers that store this resulting data will need extra spaces, energy and power sources. This data require organization and processing. Semantic data fusion models may be used for extracting meaning from data. Also, artificial intelligence algorithms should be implied to obtain meaning from this redundant data. Data storage and analysis will be a problem during all world will be connected through IoT [51]. Handling out all of the data from the IoT is a practice in Big data that applied three main steps: data ingestion, data storage, and analytics. Thus, enterprises must assimilate new technologies like Hadoop, and MapReduce. It should be able to provide sufficient disk, network, and compute capacity to continue with the inflow of new data [52], many data processing challenges are listed in the following subsections:

a) Heterogeneous Data Processing

In IoT applications, the enormous data are gathered from heterogeneous sensors such as cameras, vehicles, drivers, passengers, and medical sensors. It results in heterogeneous sensing data like text, video, and voice. Heterogeneous data processing as fusion, classification gets exclusive challenges and also provides many advantages and new opportunities for system enhancement [6]. An IoT system may include many types of sensors whose data have heterogeneous data structures. For example, IoT system may contain many forms of sensors, such as traffic sensors, hydrological sensors, geological sensors, meteorological sensors, and biomedical sensors. Each category can be separated into different forms of sensors. For example, traffic sensors can include GPS sensors, RFID readers, video-based traffic-flow analysis sensors, traffic loop sensors, road condition sensors, and so on. The sampling data from different sensors may have dissimilar semantics and data structures that critically rises the troubles in data processing [53].

b) Noisy Data

Noisy data is irrelevant data. The term was often used as a replacement for abnormal data, but its meaning has extended to contain data from the unstructured text that cannot be understood by machines. Its meaning has extended to contain any data that cannot be recognized and translated correctly by machines, such as unstructured text. Slightly data that has been collected, stored, or altered in such a manner that it cannot be recognized or used by the program that originally made it can be identified as noisy. Statistical analysis can use the information collected from old data to clear noisy data and simplify data mining [6]. Anomaly detection is the detection of irregular events or patterns that is not considered as expected events or patterns. Detecting anomalies are significant in a broad range of different fields, such as diagnosing medical problems, bank, insurance fraud, network intrusion, and object imperfections. Algorithms for anomaly detection are employed based on one type of learning formation: supervised, semi-supervised and unsupervised. These techniques vary from training the detection algorithm using completely unstructured data to having a preformed dataset with entries structured normal or abnormal. The basic output of these techniques is qualified classifiers that accept new data as input and produce suggestion for data points as output [40].

c) Massive -Intensive Data

Massive data denoted when its volume may be terabytes or petabytes in size and indicated to as Big data. All the data processing methods presented are appropriate to be applied at a data center. The data to be handled in IoT are massive data. In an IoT system, there could be a considerable amount of connected sensors, and these sensors incessantly send sampling data to the data center. The data center needs to save the latest forms of the sampling data. It also needs to save past forms of the data for some period say one week to offer query processing, state monitoring, and data analyzing. The size of data can be visualized to be massive and processing them effectively is a significant challenge [53].

IX. CONCLUSION

The IoT denotes to spreading the Internet of physical objects as a room, table, or another human sensing objects as collections of features. They can be detected, determined, and accessed by devices like actuators, sensors or other smart devices. As the vast increasing of existing devices, sensors, actuators and network communications, a massive amount of data has been generated. There are many problems result in the increasing of data volume as massive, heterogeneous, noisy data, privacy, and security. Applications of IoT have been presented. Technologies have been surveyed from the perspective of data acquisition and network based. Finally, challenges and future direction have been discussed. We intend to find new techniques and tools to solve Massive–Heterogeneous issues that are found in related work.

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