Big Data in Internet of Things: Architecture and Open Research Challenges

Iram Haider*, Muhammad Arslan Haider†, Arshad Saeed‡
Telecommunication Engineering Department, The Islamia University of Bahawalpur, Pakistan
*iramhaider765@yahoo.com
†muhammadarslanhaider3@gmail.com
‡Arshadsaeed.upwork@gmail.com

***Abstract*— Big data analytics and the Internet of Things (IoT) are currently most evolving topics in the field of technology. The leading idea behind the internet of things is that almost every device that has some mac address must be linked with each other. One of the most unique features of IoT is its real-time communication of information about these devices linked together. In the past few years, huge piles of data had been generated due to the miniaturization and diversifying of physical devices that can have mac address. These huge piles of data have compromised the storage and data collection mechanism. Furthermore, this pyramid of data is completely useless without any analytical power. However, the solutions are still in their embryonic stage and this field lacks a comprehensive study and surveys. The four main distinct features about IoT are a) data processing, data change (OTLP), and high-speed data flow (b) huge data sizes generally in TBs and PBs (c) highly diverse structural and unstructured data, query language (d) diverse source of data. This paper explores the state-of-the-art research efforts projected towards these data analytics. Furthermore, data analytic methods and technologies for mining these big data are discussed.**

Keywords— Big data, Internet of things, Data analytics, Distributed computing, Smart city

I. Introduction

Internet of things (IoT) has become so important in our daily lives that is going to make an enormous impact on advancement in technology and business by creating ease in organization and individual human. This growth of data created by IoT had played an enormous role in data analytics. Gartner described three categories of big data changes. These categories include volume, variety, and velocity [1] [2]. Immense business opportunities are present in analyzing these huge poles of IoT data. Some of the applications include smart electricity meters, grid systems and remotely monitoring the healthcare of the patient. Apart from immense opportunities, the extensive recognition, recognition and user approach of IoT has made these data analytics thought-provoking. The reason is assortment, dispensation, and communication of big data created through different sensors in the IoT environment is becoming a challenge. International Data Corporation (IDC) predictions indicate that the big data market will surpass 274.3 billion dollars with a five-year compound annual growth rate (CAGR) of 13.2 percent for years 2018- 2022. IoT BDA (big data analytics) can be explained as steps in which a variety of IoT data can be inspected including revealing trends, hidden patterns, unseen correlation, and addition of new information [3]. Companies and individual human being can get benefit from analyzing and processing these data generated. Also, they can convert it into a vast expanse of data that can affect business [4]. This is the reason that BDA is positioning to aid a business sectors and other organizations to get an enhanced comprehension of data thus making well-organized verdicts that can result in overall growth. Data scientists and data miners use traditional tools to structure a huge pile of unstructured data. Furthermore, BDA objectives include collecting the required data by using data mining techniques to indicate and recognize the live trends and inclinations to make new decisions [5]. Most of the data mining approaches are also used for basic analytics of data and to decode the complications and problems. Furthermore, machine learning along with statistical learning approaches are applied. Data generated from IoT devices are different from normal big data accumulated by practices in phases of properties because multiple sensors and gadgets are used to hatch the data. It involves miscellaneous characters along with noise and accelerated increase of data. It is expected [6] that the usage of the number of sensors will grow up to several more than one trillion up to 2030. This growth will additionally mark the increase in data generated. Induction of data analysis and IOT to big data needs tremendous resources. Useful resources and applications of the platform are provided by the Internet of Things (IoT) for effective communication between deployed devices. Moreover, the application of big data integration in IoT solutions can effectively solve the problem of storage, processing, visualization tools, and data analytics. In the past many studies are solely focused on the management of big data, but this research is directed at IoT Big data in terms of analytics of vast amounts of information generated. The investigation fields of the review are:

- There are many aspects that need research for solutions
- Data analytics in the IoT filed is creating various prospects in the field.
- Credible case is presented

Structure for big IoT data analytic is presented with future research aspects.

II. Overview of IoT and Big Data

Over view of big data and IoT is provided.

A. IOT

IoT or the internet of things refers to billions of devices that are connected to the internet and have some physical address or IP address simultaneously assembling and distributing data. With the invention of reasonably inexpensive and tiny integrated circuits and the wireless network, it is now possible to turn anything, from small needle to huge ships, into the share of IoT. Assembling these diverse things to the internet and accumulating sensor, makes them digital intelligent devices that would otherwise seem handicapped as compared to recent advancement in technology, enabling to transfer information in minimum time without the need of human interaction to do so. The internet of things is producing a network of smarter, and responsive devices around us [7]. IoT has witnessed its recent applications in developing smart retail, smart water irrigation, smart transportation, and smart production facility [5]. IoT has created a new trend in last year's where transportation facilities, home applications, and mobile devices are used as data obtaining equipment in IoT. A large number of communicating devices are converted to sensing devices in the real world. These devices are connected through Bluetooth, ZigBee, GSM, and Wi-Fi. Those devices convey information and collect instructions from remote control gadgets and devices. It makes possible straight incorporation with real-life to advance existing living standards. More than 50 billion devices such as laptops, smartphones, and game consoles are connected through several heterogeneous networks allowed by technologies. It includes RFID and wireless sensor network [8].

B. Big data

A massive pyramid of data, containing piles of information is produced by intelligent gadgets, sensors, online social connecting platforms, and various other intelligent devices. They are continually producing a large amount of structured and unstructured data. This immense generation of information results in Big data [9]. The traditional catalog of storage classifications is inefficient for the dispensation of this vast quantity of information that is continuously increasing. The tag of Big data has been unceasingly called in former literature but is a comparatively novel field of IT. McKinsey Global Institute describes big data as a set of data that are improved database classification tools than outmoded tools for collecting and storing with dispensation for analyses of data. "Studies conducted by Digital Universe [9] explains the data technologies as a fresh breed of data technologies and architecture that extracts value from the huge pile of collected information in several arrangements by allowing the high pace of capture, analysis, and discovery. Apart from all definitions of big data, some studies declare that the basic characteristic of big data is solely based upon its volume.

C. Big Data Analytics

The processing of searching database, analyzing data, and its mining to optimize companies' performance is called Big Data Analytics (BDA). It is simply the procedure of examining a huge amount of data that may contain a variation in categories of data to identify concealed patterns, correlation is hidden, customer's preference, or any other information that may affect business is called Big Data Analytics. This analysis of data gives a tremendous amount of data that affect the growth of a business. Thus, the major objective of this data analysis is to improve understanding of data and consequently making up-to-date verdicts assisting business associations. These analytics require tools that convert a big quantity of raw data into more understandable information. The algorithms used in those tools must identify patterns, trends, and correlation in data, making big data a thoughtful task of applications because of its density and extensibility of algorithms [10].

III. CURRENT ANALYTICS SYSTEMS

Diverse categories of analytics systems are utilized depending upon the requirement of IoT applications. These are briefly discussed in the subsection under real-time, offline, BI analytics, and memory level analytics.

A. Real time

In real-time analytics, the data is changing continuously and rapid and efficient data analytics tools are needed to deploy that can extract information from Raw data. Real-time data is generally generated from sensors. For analyzing data that is changing in real-time, two architecture are proposed namely parallel processing clusters and memory-based computing platforms. Hana and Green Pump are an example of instantaneous analytics architecture [5].

B. Offline analytics

Offline analytics is utilized when rapid information from Raw data is not needed. This type of analytics saves internet enterprise cost of data format conversion. Chukwa, Kafka, and time tunnel [18] are an example of offline data analytics [11] [12].

C. BI analytics

Usually, data is imported to the BI analysis environment when the size of data generated from IoT devices and sensors is greater than the capability of the database to store it is called BI analytics [13]. Currently BI can only store data in TBs. usually, BI analytics is used to determine new business opportunities in a flood of data. Sorting out new opportunities and implementing efficient strategies that help the long-term stability of the business.

D. Massive analytics

Massive analytics is applied where the size of data generated by IoT devices exceeds the entire capacity of BI analysis and traditional databases. [14] Hadoop distributed file system is used for data storage and mapping of data analytics for massive analytics. This type of analytics is utilized to create foundations of business startups and increasing the competitiveness of the market by mining suppressive data. Massive analytics eliminates the chance of risk in business decisions by obtaining accurate data.

IV. BIG DATA ANALYTICS METHODS

The main aim of big data analysis is to extract information that helps to predict future market trends, identifying recent market trends, and exposing hidden information, and ultimately make decisions on basis of these parameters. The data mining process is utilized for problem-solving methods &

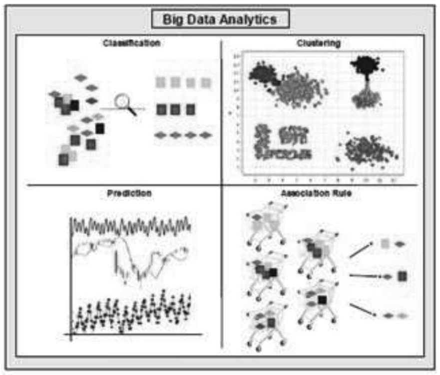

Fig. 1. Overview of big data analytics method

generalized data analytics. With the evolution of big data from IoT, analytics requirements are greatly changed. Big data management includes capturing, storing, preprocessing, and analyzing. Traditional data analytics usually have a matching or sometimes slower dispensation speed than traditional data analytics. The main emphasis while big data analysis is to get the cheapest price for maximum capacity, reasonable speed rate to fill the advanced needs of large categories of data [15]. Big data analytics are presented by classification, association rule of mining, clustering, and estimation classes. Fig1 is presented to portray and review these groupings. Information analysis and extraction are performed by special algorithms that are involved in data mining function. For example, Bayesian network, k nearest neighbor (KKN) support vector machine (SVM), and similar classification methods. Furthermore, hierarchical clustering and partitioning are spread over a wide range in clustering [16].

✓has support

- not obvious

Classification requires previous data as exercise information to train and distribute data in various categories [17]. A predefine category of data is available and the objective of predicting a group or class of object is achieved. The predicting or classification of data is made by several tools such as the Bayesian network suggests the model interpretability. They are utilized for analyzing complex data structures extracted by big data instead of conventional data arrangements that are used customarily. Clustering is another data mining practice utilized for mining big data. Unlike classification, clustering is an unsupervised mining approach. In this technique, data is divided into groups based upon their meaningful features.

The predictive analysis used previously, stores data as training data to identify a trend in data. SVM and fuzzy are algorithms that are usually utilized to determine the relationship between the dependent and independent data and predicting future curves mostly in case of disasters.

V. USE CASES

Some use cases are for big data analysis are shown in this section. The cases discussed are most frequently used in IoT applications. Also, the volume of data produced from these applications is discussed for the purpose of analytics [18].

A. Smart metering

Smart metering is an application of IoT where a huge quantity of data is generated from diverse categories of applications, which include water flows, tank level, smart grid, and stock calculation. The data generated is huge in amount and requires a powerful machine and takes a lot of time [19]. collecting data from smart meters in IoT and then further analysis helps in predicting consumption. Furthermore, analytics of data from smart meter helps to forecast demand and prevent any crisis in supply chain demand thus satisfying the objectives of ideal rating strategies. Consequently, businesses and corporations are supplying goods that must be able to cope with a large amount of data through data administration and advanced survey to convert this raw data into usable perceptions

B. Smart Transport

Smart transport is an advanced IoT bases system designed to favor the concept of an intelligently smart city. A nifty conveyance structure is designed for the influential innovative public connection system for the organization and administration of masses of the public in the advanced concept of smart cities. Conventional public transport structures that are solely grounded on image processing are prone to fail due to external factors such as heavy rain of dense fog. As a result, the image is blurry. Although the design of the e-plate system [20] using RFID provides a good resolution for management and monitoring, identification of vehicles, and tracking. The fusion of IoT to automobile type of machinery will help to control the stream of traffic resulting in better performance than the infrastructure that currently exists. Furthermore, this concept can also advance the existing traffic system in which cars can thoroughly interconnect with each other without humanoid interaction.

C. Smart supply chains

Embedded sensor technology is capable to connect bidirectionally. So, it can afford wireless access to over 1 million supply chains. Data generated by smart chains are utilized by on-position and off-position operators to execute and analyze to make suitable verdicts resulting in a rise in machine time and enhanced quality of customer services. IoT enables production facilities will able to communicate data from the predefined parameters resulting in optimizing performance by changing workflow [3].

IoT infrastructure will further allow in-transit visibility to play its character in upcoming supply chains. In transit, visibility is technologies that include RFID and GPS which provide current position setting identification and chasing data. Big data will be the backbone of these supply chains and backed by IoT. Data collected through GPS and RFID will allow administrators to commence computerized consignment and accurate delivery. Similarly, managers can monitor other parameters such as temperature and humidity which further affects quality.

D. Smart farming

Smart farming is an advantageous case for IoT. In the agriculture sector sensor are used to accurately monitor the agriculture field resulting in optimum output.

TABLE I
USAGE OF DATA MINING FOR IoT

Method	Disaster management	Healthcare	Medical Imaging	Human Genetics	Market Analysis	Industry	Speech Recognition	Bioinformatics	NLP	Social Network Analysis	e-governance
Classification	-	-	✓	-	-	✓	✓	-	✓	-	✓
Clustering	-	✓	✓	✓	✓	✓	-	✓	-	✓	✓
Association rule	-	✓	-	-	✓	✓	-	✓	-	-	✓
Prediction	✓	-	-	-	✓	-	-	-	-	✓	-
Time Series	✓	-	✓	-	-	-	✓	-	-	✓	✓

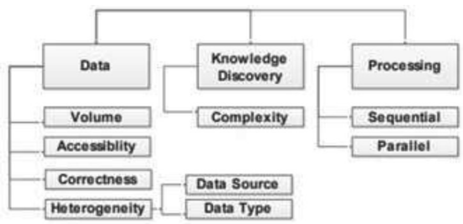

Fig. 2. Mining issues in IoT

Data obtained on moisture level, the diameter of plants, humidity, and micronutrients are transmitted to the database by utilizing network and communication devices. These databases permit through IoT gateway through the internet as shown in Table.2

VI. CHALLENGES

IoT and big data analytics although has been broadly acknowledged by several administrations but this technology is still in its initial stage. In this segment, we are addressing several encounters in the ground of IoT as described.

A. Privacy

Although data in IoT is generated from the anonymous user privacy issue may arise. It can happen when the system is compromised to restore private or particular data using big data analytical tools. Privacy issue arises in data mining domain and is currently becoming a major issue in big data. Further, the systems don't provide (SLA) solid service level agreement conditions ensuring prevention of personal information theft or misuse. As a result, more and more individuals are feeling unenthusiastic to trust these IoT based structures. Although temporary measures like identification, data encryptions, and anonymity offer a variety of solutions to administer data secrecy and concealment. So, we have to make the decisions by securing moral aspects such as what we have to use, how should we use it, and why it should be used, for the data generated from IoT. Safety risk arises further level with heterogeneous types of devices used to generate data, like raw devices, communication protocols, and data categories. These devices are designed to communicate with cooperative applications. So IoT must authenticate these devices trying to communicate by assigning non-reputable identification systems to each device. Furthermore, the meta-repository of these communication network devices should be maintained by this enterprise for auditing purposes. The security issue is further increased due to diverse IoT structures that are relatively new to security experts. As a result, any attack will compromise system security and disconnects interconnected devices.

B. Data Mining

Data mining provides an excellent solution to obtaining analytical or graphic solutions to big data and generalizing the latest data. The development of IoT and cloud computing came up with a new variety of encounters for data mining and info abstraction. Figure 2 shows the principal challenges associated with data dispensation and mining [21]. Current challenges related to Data mining are Exhaustive data read/write, high velocity, high variety of qualities of big IoT data challenge survey, diverse communication, an abstraction process. The magnitude of data generated from these heterogeneous devices and diversification of data sources impose new data mining requirements [22]. As compared to smaller data sets, relatively larger data sets have additional irregularities and uncertainties. Thus, requires extra pre exercises for preparations such as cleansing, reduction, and communication [23], [28]. A further challenge arises in the extraction of particular, precise, and conversant data from a huge pile of miscellaneous data. As a result, locating required data from composite statistics needs analyzing power and consequential associations between a variety of data points [24].

Parallel processing, sequential programming models, and a range of proposed algorithms have been introduced by researchers aiming at minimizing query response time with the production of big data. Moreover, researchers have categorized the current mining algorithm in diverse behaviors to:

- Advance single-source data encounter
- Investigate and evaluate dynamic data mining approaches
- Implement data mining methods for multi-source platform

TABLE II
COMPARISON OF BIG DATA ANALYTICS USE CASES

Use cases	Benefits	IoT devices	Data source	Big data analytics applications
Smart metering	Predict electricity consumption	Sensors	Text	Hadoop
Smart transportation	Advance current traffic operating structure by which automobiles can efficiently interconnect with each other in an organized sequence without any kind of human involvement.	Sensors, cameras	Text, video, audio	Hadoop, Spark, Hive
Smart supply chains	Allow a supply chain to implement according to the determined inputs and switch according to the peripheral location.	Sensors, mobile, devices	Text, image	Hadoop
Smart agriculture	Determine the moistness of loam, average span of plants, micro climate state and moistness level; predicted climate	Sensors	Text, image	Hadoop
Smart grid	Improves consistency, protection, and competence, along with rapid control and monitoring	Sensors	Text	Hadoop
Smart traffic	Determine the existence of automobiles, motorcyclists, and walkers	Cameras	Video, image	Hadoop, Spark

Thus, parallel k method algorithm and parallel association rule mining methods are presented. Moreover, due to different data mining methods, management problems might happen in parallel computing. This bottleneck of data in mining is becoming a major issue in big IOT data analytics that should be addressed.

C. Visualization

IoT systems produce an enormous amount of data in relatively shorter amounts of time so visualization of this data is a significant unit in big data analytics. But due to the huge size visualization of this data is a difficult task. Due to this big data analytics and visualization should work effortlessly to get unsurpassed outcomes from IoT tenders. Challenge further arises due to the heterogeneous and diverse nature of data. Also, less response time is needed in big data analytics [24]. Cloud computing with boosted GUI services can be installed to acquire the obligatory outcomes in big data tendencies. Dimensionality reduction methods have been introducing to deal with complex and high dimensional big IoT data, but these methods are unsuitable for all types of data. Similarly, preprocessed data are envisaged competently and the prospect to recognize evident correlations, patterns, and outliners is high. Data stored in a remote database has more response time so data stored in the local database has less response time further requires limited bandwidth. Given that amount of data is increasing another challenging task in visualization is the requirement of enormous parallelization of big IOT data [25]. Maximum big data visualization approaches utilized today have deprived efficiency consequences, response time, and scalability. Avoiding uncertainty is a possible conscious visualization while the visual analytics process is another challenging task. Real-time analytics of big data is another challenge. Several guidelines in bid data visualization are data awareness, data quality, and meaningful results.

D. Integration

Data generated from IoT devices are in a different format. The process of providing data in a single format in a single view received from diverse springs and collect the assessment of data is called the integration of data. Integration of data comprises all the progressions utilized in the assortment of data from dissimilar Data generated from IoT devices are in a different format. The process of providing data in a single format in a single view received from diverse springs and collect the assessment of data is called the integration of data. The integration of data comprises all the progressions utilized in the assortment of data from dissimilar sources and sorting it in a united interpretation. Respectively, every instant produces diverse arrangements of data from social media, IoT devices, and other communication and telecommunication approaches. These data are organized into:

• Structured, that has data deposited in a conventional database in form of tables with rows and columns.

• Semi-structured includes data stored in HTML and XML files

• Unstructured, which includes data stored as audio, videos, and image data.

The merging of diverse data types of different types of systems and applications is a complex process. An alternative encounter is to adjust structures in semi-structured and unstructured data before the integration and analysis of these categories [25]. Currently, the extraction of textual data is easy by means of accessible technologies in the times of text mining, machine learning, and natural processing. In parallel, new algorithms should be designed to collect and figure out the images, videos, and relevant formats from other non-text data.

VII. CONCLUSION

With the ever-increasing fusion of sensors and smart devices frequency increasing data has enlarged considerably in the previous years. Today big data and IoT are in the development phase where dispensation, renovation, and analysis of data at high frequency are essential. In this paper, we concluded the investigation in the framework of big IoT data analytics. In the first portion, recent analytic solutions are proposed. Then methods, types, and mining of big data are explained. Some credible cases were also presented. Finally, we compared IoT devices, data formats, and big data analytics applications.

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