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Value Based Care in Healthcare Environment Providing Big Data Security and Privacy: A Review

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Abstract: - Big data is an area that provides several approaches to explore the data sets that are too large or complex type in a systematic way. It describes both structured and unstructured data that overwhelms a business on a day-to-day basis, using powerful analytics to initiate decision-making, recognize opportunities, and enhance performance. But with the enormous rise in data usage and consumption, it results in various security concerns. Healthcare is one of the important sectors that produces a lot of data because today, healthcare switches paper-based medical records into electronic platform to store, manage, analyze and process data. It is witnessing a tremendous increase in the volume of data in terms of complexity, diversity and timeliness. Here we have also explored through various challenges and opportunities in big data analytics in the medical field. Health data is also extremely sensitive, with confidentiality and integrity as a key attribute. Hence the security of the data and the need for preserving privacy of the patients in healthcare environment has become vital. So, this study mainly focuses on the security and privacy methods adopted to handle big data in the healthcare sector. Also, we have presented various issues and opportunities in the field of medical care while leaping forward to big data environment.

Keywords —Big Data Analytics, Big Data Security, Healthcare, Privacy, Security, Value Based Care

I. INTRODUCTION

With the increase usage of internet worldwide, almost all of the fields have drastically changed with latest technologies that results in generating a massive amount of data, say from kilobytes to thousands of terabytes that has to be created, replicated, and consumed. As the size of the data increases, traditional data processing software's couldn't able to achieve the expectations due to storage limit and processing speed which results in a need to collect, store, process, manage and analyze the data properly without any ambiguities. Over the last decades, there has been developing some sort of eagerness about the hypothetical usefulness of handling all these data, termed as Big Data. Despite the term Big Data have become omnipresent, there is no universal definition for it until now. But it mainly refers to the large and complex datasets that can be stored, managed, processed and analyzed to reveal some valuable information for improving business aspects. Commercial Industries, governmental institutions, Health Care Providers, and economical as well as academic institutions, are all taking advantage of the potency of Big Data to boost business scenarios which mainly aims at the enhancement of customer experience. IBM a company that runs businesses whole over the world generates nearly 2.5 quintillion bytes of data day after day. Hence for sure we can say that Big Data has pierced almost all the of industries today and has become a central governing force behind the achievement of ventures and organizations across the globe.

This paper focuses mainly on the healthcare sector that is booming at a faster pace since the requirement to manage patient care details and innovate medicines has increased synonymously. A new pattern of modernization has been in wide spread in global healthcare sector. Moreover, the digitization of health and patient records form traditional paper based recording results in abundant data that is collected from various sources like electronic health records (EHRs), medical imaging, search engines, smart phones, genomic sequencing, payor records, pharmaceutical research, government agencies, research studies, wearables, and medical devices as given in *fig 1.1*. It is witnessing a tremendous increase in the volume of data in terms of complexity, diversity and timeliness undergoing drastic and fundamental alteration in clinical, operating and business model in the world economy itself for the anticipatable future. This shift has encouraged by aging populations, lifestyle changes, explosion of various software applications and mobile devices for innovative treatment, evidence-based medicine, increased the focus of quality of care and value. All these factors offered significant opportunities for supporting scientific assessment, improving healthcare distribution, surveilling disease, management and policy creation, optimizing treatment for various ailments and monitoring undesirable events. The medical costs also reduced as a result of a change from reactive to proactive healthcare. While utilizing the power of data, threats and vulnerabilities will continue to grow that

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gives more focus on security and privacy. Hence, it is essential to implement healthcare data security solutions for protecting important resources satisfying healthcare compliance mandates [1]. Hereafter, we will look through some data security approaches specifically for healthcare sector, that will help in protecting the medical data as well as patient privacy.

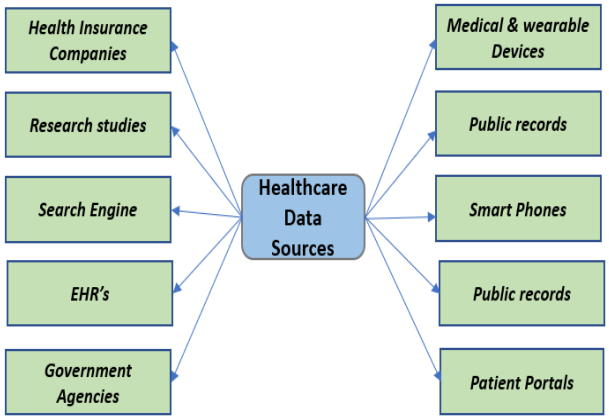

Figure 1.1: Sources of data in healthcare sector

This paper has organized in such a way that Section 2 describes the concepts of big data in healthcare, its characteristics and properties, Section 3 represent conceptual architecture and major challenges faced in this field, Section 4 & 5 covers various security and privacy approaches employed as well as the opportunities in the field of healthcare.

II. CONCEPTS OF BIG DATA

According to McKinsey Global Institute it refers to *datasets whose size is outside the capacity of typical database software tools to capture, store, manage, and analyze [2]*. In *[3]*, the author proposed the widespread description of big data with the '3V's': *Big Data is volume, high-velocity and high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making*. Some others also, characterize big data by a fourth 'V' that is Veracity which focus on legitimacy, quality, and trustworthiness of data. The 4V's are the main factors that influences big data which is explained as below.

Velocity: It is the speed and frequency at which data is generated, captured and shared. Consumers as well as businesses now generate lots of data and in most shorter cycles, from hours, minutes, seconds down to milliseconds.

Volume: It is the amount of data produced by organizations or individuals. All organizations are searching for ways to handle the ever-increasing data volume that's being created every day.

Variety: It is the proliferation of new data types including those from social, mobile and machine resources. New types include content, metrics, mobile, physical data points, process, location or geo-spatial, hardware data points, machine data, radio frequency identification (RFID), search, and web. It also includes unstructured data.

Veracity: It is defined as the confidence or trust in the data. It actually refers to the reliability of the data source, its context, and meaningfulness of it to the analysis based on it. Incorrect data can cause a lot of problems for organizations. Hence, organizations need to ensure that the data is correct as well as the analyses performed on the data are correct. In automated decision-making, where no human is involved, we need to be sure that both the data and the analyses are correct.

In addition to this nowadays a number of other V's have been added to this. Some of them are listed as below.

Value: It is defined as the ability of the big data to transform data into appropriate indications that helps in different business purposes.

Variability is different from variety. A coffee shop may offer 6 different blends of coffee, but if you get the same blend every day and it tastes different every day, that is variability. The same is true of data, if the meaning is constantly changing it can have a huge impact on your data homogenization.

Visualization is critical in today's world. Using charts and graphs to visualize large amounts of complex data is much more effective in conveying meaning than spreadsheets and reports chock-full of numbers and formulas.

Volatility means the organizations should make sure that how long their data needs to be kept to consider as irrelevant, historic or not useful. For this proper rule has to be established for data currency and availability as required.

Validity is sometimes similar to veracity and defines the accuracy of the data. Before doing any sort of analysis, data scientists spent most of their time for cleansing the data. Big data analysis will be benefitable only if there are good data governance practices ensuring data quality, common explanations and metadata.

III. BIG DATA IN HEALTHCARE SECTOR

Big data by eradicating scam and exploitations has created a big transformation in the field of healthcare providing better outcomes. It also contributes to a large percentage of healthcare costs. The healthcare industry generates massive amounts of data about each and every suffering person but accessing, managing, and interpreting that data is vital to generate actionable visions for better care and efficiency. Clinical practices likewise assume a function in the rise of information in medical services. Earlier doctors used their own experience and judgements to make treatment decisions, however the most recent

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couple of years have found a shift in the manner these decisions are being made. Nowadays, Physicians review the available clinical data from various sources, the possible treatments and medicines, and their side effects with the help of modern technologies and make a well-versed decision about a patient's treatment. Money related concerns, better insights into treatment, research, and productive practices add to the requirement of big data in the medical care industry.

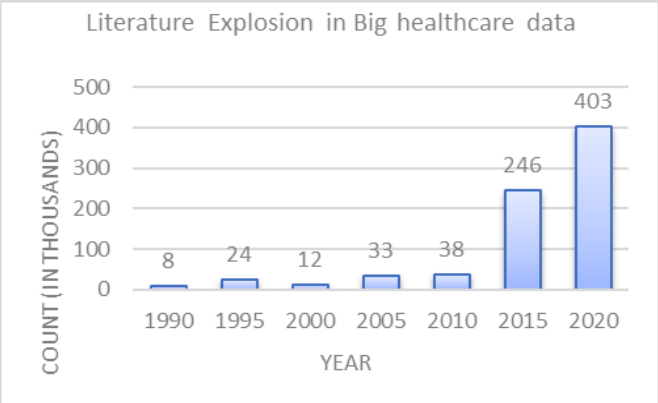

Figure 3.1 Literature explosion searched with 'Big healthcare data' in PubMed

In traditional systems, the clinicians use structured data for prediction but since the data is increasing and they can have multiple forms which results in unstructured data that arises from internal as well as external sources. For the proper storage, maintenance and analysis of these data requires modern analytical tools and techniques so that the visualization of new patterns helps in diagnosis as well as prediction of new diseases. These predictive analyses could help to reduce the wide spread of epidemic diseases like Ebola, Covid-19 etc. Since the new technologies like Big Data, Internet of Things, Machine Learning, Data Science, Cloud Technology, etc are incorporated in the medical field, they could able to focus more on enhanced quality and patient care by proper analysis. In figure 3.1, we have shownn a statistic of data explosion in healthcare as in 1990 it was only 0.8ZB but in the year 2020 it has raised to 40ZB. This rise has result in more literature explosion as well.

A. Conceptual Architecture

In figure 3.2 we have shown a conceptual architecture of big data technology in healthcare environment. Various steps involved are discussed below.

Data Capturing: - Data comes from various sources and can be in different formats. For proper analysis and interpretation, the collected data should be clean, complete, accurate and formatted so that it can be applied to multiple systems. In one recent study at an ophthalmology clinic proved that poor EHR usability, convoluted workflows, and an incomplete understanding of the importance of big data to capture well can all result in quality issues that will wave data all over its lifecycle.

Data Transformation: - Data cleaning is an important area in big data processing as it is a process that ensures the accuracy, consistency, relevancy and integrity of the datasets. Data to be analysed collected from various sources can be in different formats, so there is a need to clean or scrub the data properly to infer new information. Earlier most of the cleansing processes are done manually, but nowadays some IT vendors are offering automated tools to compare, contrast and validate the datasets. Due to the popularity of machine learning techniques these tools have become more precise which results in time and expense reduction ensuring high accuracy and integrity in healthcare data warehouse.

Data Storage: - Physicians and health workers are rarely aware about the storage of data, but for IT department it has become critical in terms of cost, security and performance. Many of the organizations prefer on premise data storage, but on-site server can be expensive to scale, difficult to maintain, and produces data losses. In order to overcome this issue, cloud storage has become a popular option. According to a survey report, almost 90 percent of the healthcare organizations are using cloud-based services in terms of infrastructure, software and applications and should be very careful about healthcare specific compliance and security issues. However, the most flexible and workable approach is a hybrid infrastructure approach, providers should be careful to guarantee that dissimilar systems can share data and link together when necessary.

Security: - Security should have a high precedence as a lot of high-profile breaches, and hackings results in various vulnerabilities these days. The Health Insurance Portability and Accountability Act [9] includes a long list of security and privacy rules for organizations storing and sharing protected health information (PHI). In practice, these safeguards translate into common-sense security procedures such as using up-to-date anti-virus software, setting up firewalls, encrypting sensitive data, and using multi-factor authentication.

Stewardship and Metadata: - Medical data has a long shelf life and should be kept for at least 10 years. Analysts utilizes these data for research purposes and also for quality measurement and performance benchmarking. Understanding when the data was created, by whom, and for what purpose – as well as who has previously used the data, why, how, and when – is important for researchers and data analysts. Creation of metadata is vital for scientific studies and the need for a data steward can ensure the standards and formats of all documented elements from creation to deletion.

Big Data Analysis: - This step involves steps like querying, reporting and visualization. Querying is essential for proper reporting and analytics. The organizations should overcome

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the interoperability problems that prevent the tools from accessing the data repository. After query process, the analyst has to generate reports that is clear, concise and accessible by the users to draw his or her own inferences about the data spectrum. Visualization helps the clinicians

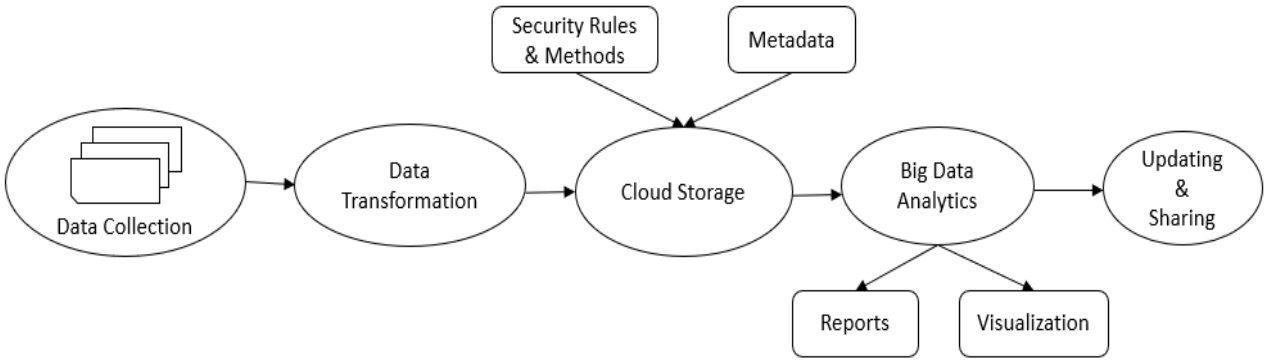

Figure 3.2 Architecture of big healthcare data analysis

to view the results and use it appropriately. Color-coding, charts, histograms, scatterplots etc are some of the commonly used visualization tools in big data analytics.

Updation and sharing of data; - Data will not remain static, it will be changing each and every second. So, it is major challenge to continuously monitor the data assets. The providers should have clear idea about manual updation and automated updation of these datasets without any comprise in the quality and integrity matters. Also, they must be aware about the duplicate records while updation which makes it difficult to access information for patient decision-making. In order to construct a big data exchange ecosystem, sharing data and tools with external parties is essential for value-based care. Advance tools and techniques like FHIP, public APIs etc help developers to share data easily without security concerns.

B. Issues faced by healthcare sector

As in every field, increase in demand results in more challenges and opportunities. Every organization faces some issues regarding data storage, accessibility, quality, integrity, privacy and security. Medicare industries mainly faces issues regarding security and privacy, data retention and data management.

Issues: - Issues with data capture, cleaning, storage and retention is one of the key challenges of healthcare analytics. Since the volume and variability of data is increasing, collection of appropriate data and transforming the data to preferred format is of important. In healthcare the data that is extensively used is self-reported data and it should be consistent [6]. Keeping information up to date as well as accurate is a challenge of data collection. Data structure related issues are addressed in lot of articles [10,11,12]. It is essential for the big data applications to be more transparent, user-friendly and menu driven so that the data processing can be simplified. Most of the available data are unstructured mainly from the natural language processing which is fragmented and rarely standardized. Data standardization [11][17] and cleaning is another issue that should be done with utmost care since it results in less efficiency, integrity and accuracy. As the data is used for research purposes, and it has to be shared with different applications and technologies proper standardization is required. Also, it has to be maintained for a longer period and proper storage mechanisms like cloud-based technology [22] should be selected which provides additional security layer for extraction, transformation and loading of patient records.

Privacy and Security are the most important issues faced by the healthcare businesses. Data hacking [20][21] will be extremely profitable for the hackers and harmful for the organizations. Electronic health records may contain details of personal as well as financial details which result in identity theft and even blackmails. It is illegal to share these sensitive data without prior permission which causes financial costs and reputational costs which may remain for long periods and are harder to measure. HIPAA formed in 1996, to protect privacy and secure sensitive data. All healthcare providers must focus to meet the HIPAA rules by implementing data protection through masking and encryption methods to avoid illegal access of data.

Most of the patient records these days are stored in a centralized database for quick and easy access, but the real challenge lies when this data has to be shared among outside medical practitioners. Although EHR data within the healthcare environment may follow common standards, but pharmacies, external healthcare providers may use different systems which makes sharing and integrating medical records a cumbersome task. The medical records

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maintained by the healthcare providers and the billing department on the hospital floor need to be reflected accurately while making insurance claims. But often, there is a lack of integration between the administrative and clinical systems with mismatch among data management systems and a variation exists among treatment codes and care given to the patients.

IV. SECURITY AND PRIVACY STRATEGIES

Security and privacy are the two important concerns and challenges faced by most of the organizations worldwide when it is related to big data. Security is important for protection of data but it is inefficient to address the problems of privacy. Security and privacy are two terms that should be acted independently for the efficient management and quality of the data as well as the organizations. Security mainly focuses on the confidentiality, integrity and availability of the data. Main intention of security is to safeguard the data from unauthorized access. While privacy is the term used to safeguard the user's identity. Differences between the terms has been mentioned below in the table 4.1. Security is important to protect the data from any sorts of vulnerabilities but it is not sufficient for providing privacy to the users.

Security	Privacy
Protection against unauthorized access	Protect personally identifiable information
Protection for all types data including electronically stored information.	Protection for sensitive information related to individuals and organizations.
Security can be achieved without privacy	But good privacy cannot be achieved without good security practices.
Security protocols are used for maintaining confidentiality, integrity and availability of assets	Privacy protection rights are used for protection and processing of personal data.
For example, an organization uses various technologies like encryption, firewall etc. to prevent data compromise or vulnerabilities in the network.	If a patient has to pay the bill, he will be giving his name, address, treatment details etc., but the providers are not supposed to share the details to any third party without prior consent of the user.

Table 4.1 Security Vs Privacy

In [6] the author Kin et al. claims that big data security present mainly three factors like data security, access control and information security. Yazan A. et al [7] proposed a big data security lifecycle model that comprises of four phases like data collection, data storage, data processing, and knowledge creation. The main focus of this paper was to coin out various threats and attacks that affects the big data environment within these phases. As an advancement to this Kanika et al. [25] developed a security model with five phases including data creation phase, data collection phase, data mining phase, data analytics phase and decision-making phase explaining threats and their solutions through different phases of the life cycle. At all the stages it includes confidentiality, integrity and access control mechanisms.

A. Security Threats and Solutions

As mentioned above each phases of big data security models are vulnerable to different threats and attacks. Data collection phase are vulnerable to attacks like phishing, spoofing and spamming. To prevent this Thilakanathan et al. [26] proposed encryption methods like double encryption, symmetric encryption and ElGamal algorithm. Major threats to data integrity was faced in the data transformation phase. Content Based attacks, distributed/denial of service attacks affecting the infrastructure from inside and outside the organization are commonly seen in this phase. Data mining attacks, re-identification of patient information is maintained by a double layered architecture [27] [29] using AES and RSA algorithm. Finally, the information generated by data modelling is very crucial that should not be disclosed publicly. So, this phase is vulnerable to various privacy issues and phishing attacks targeting the decision makers. Proxy based complete homomorphic encryption [30] and Group Signatures [31] are proposed as a solution to these issues. Various technologies are available to ensure security and privacy of big healthcare data.

- Authentication: - ensure the authenticity of a user by protecting the identities of users and secure access to corporate networks. Hashing techniques, like SHA-256, Kerberos mechanisms, and Bull-eye algorithm can be used for monitoring all sensitive information to achieve authentication.
- Encryption: - An efficient way of preventing unauthorized access to data is data encryption. It protects the ownership of data throughout its lifecycle and useful to avoid packet sniffing and theft to storage devices. Health providers must make sure that it is easy to use and efficient too. Furthermore, the number of keys used by the parties should be minimal.
- Data Masking: - Replaces important data with some unidentifiable elements. Since it is not an encryption method, the original value cannot be reverted back. It is a most popular approach for data anonymization which reduces the cost of big data deployment avoiding the need of any additional security.
- Access control: -Access to a system is governed by certain access control policies based on some privileges and rights given to the users. It is the most powerful and flexible mechanism granting permission for the users. Role based and attribute-based access control mechanisms are most popular methods for EHR's.
- Monitoring and Auditing: - Monitoring is used to gather the network related events to catch the intrusions. Various intrusion detection models are used for this purpose. Auditing is also needed to record the user

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activities in sequential order for keeping a log of every access and modification of the data.

B. Privacy Preservation in big data

A rising concern in the field of big data is the attacks on patient privacy due to persistent attacks against information systems. A major incident reported on Forbes magazine [32] compels analytics and developers to focus more on privacy in big data. Healthcare organizations that handle bulk amount of fitness-related data must meet a series of requirement in order to ensure privacy of data [33-35]. They are access to confidential information, secure storage using electronic media, back-up copies of all data, encryption of data, use of physical media for confidential information, and system for managing security related incidents. Privacy-preserving techniques fall into the following categories: data modification techniques, cryptographic methods and protocols for data sharing, query auditing methods, statistical techniques for disclosure and inference control, and randomization and perturbation-based techniques.

Privacy laws: - In 1981 European Convention on Human Rights was the first in the world to address privacy issues related to automated processing. It was set out to ensure every individual to secure his or her privacy in preserving personal data regardless of nationality or residence. The convention expressly prohibits the processing of data unless the law provides appropriate safeguards. As a result, it is unlawful to process medical information about a person unless one has a legal basis to do so, such as an existing doctor-patient relationship. Different countries have laws and policies for privacy protection.

Privacy preservation methods: - Some of the methods used are mentioned below

- De-Identification – traditional method prohibiting the disclosure of confidential information by removing some identifiers or by using some statistical methods to delete enough information. But it is not that much useful, hence concepts of K-anonymity, l-diversity and t-closeness have been introduced to enhance this method.
- Generalization: - In this method most of the data available has been generalized. For example, Birth field has been generalized to year and Zip code to wider area which provides data anonymization.
- HybrEx: - is a hybrid execution model in cloud computing for confidentiality and privacy. This model uses both private as well as public cloud for processing and sharing of data. If the organization reports that no privacy and confidentiality risk is there in exporting the data, then it will use the public cloud, whereas for the computation of sensitive information private cloud will be used. If the application requires both private and public data, then the application itself partitioned and runs in both private and public clouds.
- Identity Based anonymization: - Mainly intended to privacy protection that sanitizes information. Here the person whom the data describes remain anonymous with certain encryption methods.

V. OPPORTUNITIES

Despite the challenges of big data, advanced analytics offer a lot of opportunities in the health care industry in terms of cost, quality, and access. Some of them are mentioned below.

Big data has a great potentiality in improving the quality and value-based care. It can predict outcomes with the help of available historical data and ensure standardization of industry-wide care [20,37]. Quality can also be improved by the efficient use of information that helps in analyzing real-time resource consumption throughput. The use of predictive analysis can also help in the reduction of readmission of patients by classifying them on the basis of risk of readmission. Management of population health specially focusing on aging of the population and age-related health issues both locally and globally has become more salient nowadays [38,39]. By using analytics in health management, healthcare contributors can be able to identify patients who are at high risk by effectively reviewing problems, diagnosis, and analysis of lab results through EMR. Early detection of diseases is another opportunity of big data analytics which assists in achieving improved treatments and higher patient outcomes. It can also help in preventing deadly illness and can track and monitor healthy behaviors and conditions [40][39]. Decision making process can be improved with accurate and up to date information motivated by new technologies and treatment procedures within clinical research. Increased use of technology has shifted the medical sector form disease centric to patient centric care allowing the availability of information directly to the patients [40]. Fraud detection, globalization of data, threat detection are some of the other opportunities mentioned in the literatures.

VI. CONCLUSION

Health care systems with a shift from traditional methods to more advanced technologies results in great amount of data known as Big Data. These data can be stored, processed and analyzed with various methods so that new information or inferences can be generated for the value-based care. A conceptual architecture has been discussed here describing the process involved in big data analytics in the field of healthcare. It helps in early detection of diseases, reduction in costs, management of population health, reduction in readmission of patients, easiness of decision-making process etc. Other than the opportunities, various issues also have been discussed in this paper, giving more focus on the

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security and privacy concerns. Since the importance of inferencing and analysis of big data is rising in every fields, more security and privacy preserving tactics have to be followed to ensure confidentiality, integrity and availability incorporating cloud-based technologies.

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