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Overview of Data Management In IOT Network For Industry 5.0

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Abstract : Technological transitions characterize the current era. One of them is the Industry 5.0, which is the revolution of humans and technology. The IOT (Internet of Things) technology is emerging as the backbone for every application of Industry 5.0. In the current paper, we do review Industry 5.0, applications of Industry 5.0 and IOT networks. This review focuses primarily on the management of data for the number of nodes that are connected in the IOT network , which generates a large amount of data that comes in both structured and unstructured forms. Data management is the key area of research for efficient interoperability of IOT networks. Moreover, it highlights the challenges requiring attention for successful data integration.

IndexTerms – IOT network, Data Integration, Industry 4.0, Industry 5.0, Machine Learning.

I.INTRODUCTION

The revolutionary shift termed "Industry 5.0" is projected to be centered around human beings and to empower their creativity, problem-solving, and decision-making by utilizing advanced technology such as Big Data and AI, through an industrial revolution that is termed "people- centric." In Industry 5.0, technology is not there placement of humans, but is rather considered a tool that hasthepowertoelevatehumancapabilitiesandsupportthemtoattainbetterresults. Conversely, the Society 5.0 movement, which has its origin in Japan, aims at creating an entirely new society that would be integrated with modern technologies such as Big Data, AI, and IoT, besides ensuring a better quality of life and solving social problems. The concept of "human-centric innovation" is the cornerstone of Society 5.0, which revolves around placing humans at the forefront of technological advancements with the goal of creating a better society for everyone. Industry 5.0 is the modern society's demand.[1] The phrase Industry 4.0, which is regarded as the fourth industrial revolution, means to integrate virtual and physical worlds in an industry for better productivity and efficiency through the highest level of automation. However, since Industry 4.0 will not be able to satisfy and cope with the rising demand for customization, the term Industry 5.0 has been proposed for individualized production and human support in manufacturing. The birth of the term Industry 5.0 shows different interpretations of the definition and the aspects of the union between humans and machines [2].

Industry 5.0 represents a concept which aims to create an ongoing collaboration between human workers and machines in the workplace. Industry 5.0 will increase manufacturing production and customer satisfaction through its emerging applications, and supporting technologies. [3] The concept of Industry 5.0 or Healthcare 5.0 and its potential applications in the healthcare field. Healthcare 5.0 uses advanced technology to transform healthcare delivery ,improve patient outcomes, and improve the overall quality of healthcare.

Industry 5.0 focuses on integrating people, machines, and technology across industrial sectors. Challenges and obstacles to successful implementation of healthcare 5.0 Indeed, data security and privacy along with ethical and legal dilemmas represent some of the vital elements healthcare providers face. and cost-effectiveness. Healthcare systems have multiple stakeholders and components, making it difficult to integrate data seamlessly.[4] The digital transformation in the industry helps improve resource use by using technology. It mimics the actions of Cyber-Physical Systems (CPS) across the entire value chain. However, these virtual settings, which depend on machine-to-machine communication, lack human participation. Humans are central to the upcoming industrial shift known as Industry 5.0. The goal is for people to be actively involved in these digital spaces called meta verses, where they can interact with their surroundings. To support this human-focused industrial meta verse vision, we need to give people technologies that help them gain a more immersive and genuine understanding of manufacturing processes. In this document, we introduce a model that incorporates various empowering technologies, such as Digital Twins, Virtual Reality, and the Industrial Internet of Things (Riot), to work toward a human-centered industrial meta verse. To validate our framework, we have created a prototype to study human behavior in a virtual environment.[5]

Each manufacturing field is progressing swiftly with the advent of Industry 5.0, which is characterized by the integration of innovative technologies to improve sustainability, human essential, and perseverance. Logistic operations within a manufacturing plant are no exception. For this development. Industrial Internet of Things (Riot) serves as a key facilitator for the digital transformation that offers significant opportunities for companies. In this scenario, companies require a direction for the cohesive incorporation of IoT technologies into internal logistics. Lived Theoretical knowledge has not directly tackled this issue.[6]

Owing to rapid progress in technology, the agricultural industry is undergoing a significant transformation; this shifts the transformation arises from the incorporation of technologies such as Era5.0,Society5.0,IoT,AI,andRemote Sensing. The incorporation o f these technologies assists in various areas, including IoT sensors that facilitate real-time data monitoring that encompasses factors like soil conditions, weather elements, the important information regarding overall crop vitality, and additionally assist in encouraging knowledgeable Decision-making in agriculture. IoT and digital twins are enhancing farming to be eco- friendlier and smarter. Similar to virtual farms, digital twins leverage real-time sensor information. These sensors connected via IoT collect accurate information regarding soil quality, climatic trends, and animal activities. This smart information assists farmers in the digital farm by offering them through improved crop maintenance, efficient resource use, and awareness of weather fluctuations [6]

In Industry 5.0, when the infrastructure for post-disaster communication is compromised, uninterrupted communication is very critical. factory, this diverse network of satellite and multi hop systems can satisfy the demands of year-round manufacturing and guarantee consistent and reliable output for smart production systems. Considering the diverse integration of various networks in Industry 5.0 (wireless LANs, mobile communication networks 5G, wireless sensor networks, etc.), their transmission effectiveness will also be influenced by an increasing number of factors. This paper proposes a simple and easy- to- implement end-to-end transmission method relying on the characteristics of multihop.components in the industrial Internet of Things and satellite systems.[8]. The Internet of Things (IoT) is a networking approach where physical, digital, and virtual items have identification, detection, networking, and processing capabilities to interact with one another, as well as with other devices and services online, to fulfill tasks requested by users. Numerous IoT applications are designed to enhance convenience and ease daily life for humans. Moreover, the implementation of IoT technologies in the automotive sector has led to the emergence of the Industrial Internet of Things (IIoT), enabling the use of Cyber-Physical Systems where machines and humans engage with each other. Owing to the variety, complexity, and substantial amount of data produced by these entities, it's essential to examine the challenges encountered in data management within IoT networks [9].

As the industry 5.0 connect billions of devices as well as generate data in terabytes, so it us crucial to study on IOT network and data management in industry5.0 for efficient outcomes from industry5.0 applications.

II.OVERVIEW OF DATA MANAGEMENT IN IOT NETWORK:

The potential for transformation is huge so, the applications range from Internet of Things (IoT) infrastructure to data- driven governance. To effectively handle the vast amounts of data produced in industry5.0 applications, we need strict security and privacy protocols. There is a need for consistent data formats, compatibility across different systems, and continuous improvementsincybersecurity.Thisdatamanagementwillstrengthenintegrationandsupport the development of safe, efficient, and privacy-conscious data ecosystems in industry 5.0 applications.[10] The Internet of Things (IoT) is changing our connected world because more lightweight devices are linking to the Internet. As a result, thorough research on intrusion detection in the IoT area is crucial. Network intrusion data sets play a key role [11]

The Internet of Things(IoT)isnowcommonworldwide.Manydifferentdevices,likevehicles, home appliances, smart phones, and environmental sensors, connect to the Internet. This connection allows us to gather a vast amount of varied IoT data, known as IoT big data. The creation of IoT big data shows that we need efficient analysis systems for various applications. These systems can help with urban planning, tackle air pollution, and improve business decisions.[12] The Internet of Things (IoT) is set to connect devices with unique identifiers over a network. This will create a balanced system with fast speeds and large data volumes, but it also presents challenges for interoperability. The IoT data management system is crucial for achieving effective and efficient performance. IoT sensors generate and collect huge amounts of data that make up large data sets. Many studies have examined IoT data management from different angles. This paper focuses on IoT data management. The studies are classified into five categories: data processing, smart data applications ,data collection, data security, and data storage.Finally,researchineachcategoryiscomparedbasedonthisclassification.[13]Before actual data modeling process, it needs to use a series of methods to ensure that data science algorithms have accurate and trustworthy data. Often, the data comes from various sources that require integration. Furthermore, the data from these sources is frequently of low quality and may raise ethical issues. If we don’t address these problems, they could impact the final decisions made by the prediction algorithms. [14]

III.LITERATUREREVIEW

EDGE COMPUTING DATA OPTIMIZATION

One of the important elements of digital sustainability is reduction of energy footprint in relation to digital technology. There are various ways through which this goal can be achieved, and efforts to make data centers more energy-efficient, thereby minimizing the overall energy required for the functioning of the data centers. Commensurate with the development in new research efforts for Industry5.0,there has emerged a conceptual Framework for using big data in an optimized way without diminishing the essential components of the data in terms of information. As a push to the development of the conceptual framework, the need for big data analysis will be supported by the edge computing enabler, thereby allowing for real-time data tracking and analysis. Furthermore, the use of edge computing will facilitate real-time data compilation and sharing, thereby providing timeliness and importance to the data in real-time decision-making. This new way of using big data in an optimized way based on human, cyber, and physical spaces is a significant development in terms of data mining in the Industry 5.0 context. The conceptual development in edge computing and other big data management will open new doors for research in terms of smart management. The reduced big data set will, however, need additional processing before full insights can be obtained. [15]

FOG COMPUTING-BASED ARCHITECTURE FOR INDUSTRY5.0

The future looks promising for the next generation with regards to the growth of smart cities, concludes Operations and designing smart systems for IIoT devices involve different types of decision-making in various fields. The complex system has many variables and decision- making needs that in turn demand real-time data gathering through IIoT operational tools. Fog computing plays a crucial role by installing IIoT devices nearby and taking less processing time than cloud computing for smart systems. The aim of this paper is to introduce a hierarchical fog computing architecture for smart energy-supplying systems. This architecture may support many infrastructural features and provide services effectively. This paper verifies that the amount IIoT devices send to the cloud on a second basis. Besides, the development process of data analytics and machine learning methods will enable better decision-making and optimization. These will not only be used to enhance the safety of Sri Lanka but will also increase the efficiency of the entire sustainability of the system. [16]

ML-SP2,ML-IDS:

The future of the next generation in smart city development is upon us. The Industry 5.0 revolution has started a new era of intelligent manufacturing equipment. This shift is vital for our society and economy. Industry 5.0 focuses on improving human potential by combining advanced IT technology, Artificial Intelligence (AI), the Internet of Things (IoT), robots, and augmented reality into daily life, particularly in smart industrial environments. Traditional applications often struggle with the vast amounts and complexity of industrial data, leading to challenges in data analysis, security, and privacy.

To tackle these issues, this paper proposes a Machine Learning-assisted Smart Production Process (ML-SP2) and an Intrusion Detection System(ML-IDS) to address concerns in Industry 5.0.The ML-SP2 incorporates data capture, predictive maintenance, optimization ,transparent decision-making ,and proactive maintenance into the manufacturing workflow. Meanwhile, the ML-IDS identifies network vulnerabilities using ensemble techniques and ensures efficient distribution management.**[17]**

A BLOCKCHAIN-BASED FRAMEWORK

A block chain-based framework aims to transform healthcare data sharing in Industry 5.0 settings. This research combines CP-ABE encryption with decentralized IPFS storage and Ethereum smart contracts. It develops a system that protects patient privacy, follows regulations, and improves efficiency in health care work flows. This innovative frame work uses Ethereum smart contracts, decentralized IPFS storage, and cipher text-policy attribute-based encryption (CP-ABE).These improvements come from optimizations designed for Industry 5.0, user-friendly interfaces, energy efficiency through Proof of Stake (PoS), and strict cryptographic practices. [18]

A DATA-CENTRIC AI PERSPECTIVE

The majority of the time in the machine learning process is consumed by data preparation. Without good data, Even the best algorithms of machine learning cannot perform well. Hence, Data-Centric AI practices are becoming common. Unfortunately, many real-world datasets are small, dirty, Biased and even poisoned, this research focuses on data collection and data quality, mainly. The reason behind this is that it forms a basis for deep learning applications. Data collection is important, as in most recent deep learning While approaches need less feature engineering but more significant amounts of data. Regarding data quality: It also outlines methods of data validation and cleaning.[19]

RFID TECHNOLOGY:

A real-time data integration system is essential when developing an internet-of-things (IoT) based warehouse. The study used radio- frequency identification (RFID) technology to support this integration process. It showed that data integration is crucial for organizing various data frommultiplelocationsinrealtimewithintheIoT-basedwarehouse.Thestudyconcludedthat real-time data integration in IoT-based warehousing can be broken down into three main components: configuration, data basing, and transmission. However, there is still some human involvement in one of these processes. Therefore, further development is needed to remove this human intervention, although it is minimal ,by enhancing data integration techniques[20]

SEDIA: The challenges in developing smart city applications are tackled by SEDIA, a platform for integrating enriched IoT data in smart city applications SEDIA, a new platform for managing data and utilizing geographic information—particularly for creating smart city applications— was presented in this paper. SEDIA offers a complete solution for the entire data handling process: gathering ,labeling, storing, analyzing, and presenting. It focuses on adding meaning to data and understanding geographical relationships, which are often overlooked in similar research. The platform uses ontology classes and properties to label the collected data semantically. It also employs the Neo4j graph database to help recognize patterns and relationships within the data. [21]

COGNITIVE MANUFACTURING: Cognitive manufacturing is based on artificial intelligence, big data analytics, and IoT-based systems that help improve decision-making and operational precision. However, for actual implementation, seamless data integration across the IoT networks is needed to establish real- time connectivity between machines, sensors, and analytics platforms. This research underlines that fragmented data sources are major barriers that impede predictive maintenance, smart process planning, and sustainable value creation. Further the focus on integrated data architectures along with interoperable IoT frameworks gives full potential of cognitive manufacturing in smart, connected, and adaptive production environments. [22]

MACHINE LEARNING APPROACH FOR IOTAND SATELLITE SENSOR DATA INTEGRATION:
This article presents a novel approach to enhancing the spatiotemporal resolution of various environmental variables. This paper leverage machine learning algorithms to create satellite- like images at any given moment, using data collected from IoT sensors. The target variables are derived from a combination of regression models. The approach for evaluating these environmental variables, which employs a data fusion strategy to generate the satellite-like images without needing to interpolate the input variables during initialization. Instead, this interpolation occurs during the prediction phase, making the process more efficient and accurate. Plus, the effectiveness of the method can be enhanced by applying various machine learning algorithms to better understand the relationship between IoT data and satellite sensor data. [23]

BLOCKCHAIN-BASED MANAGEMENT AND ADAPTIVE CLUSTERING TECHNIQUES:

The expanding number of smart devices in Internet of Things (IoT) networks has amplified the security challenges associated with device communications. To be able to navigate the challenges in 5G-enabled IoT networks, a distributed security framework has been developed for integrating IoT devices using multiple-hop cellular networks, using a multi-level architecture with a block chain-based approach. The self-clustering EC method, it focuses on the EASISS-NEWO method, dividing the IoT network into clusters in order to enhance security and network lifespan by reducing latency, processing load, and network load. IoT safety issues such as framework privacy, authentication, heterogeneity, flexibility, and scalability are all addressed by the approach. [24]

Reference	Title of the paper	Focus	Research gap
Bajic,B.,Suzic,N.,Moraca,S., Stefanović, M., Jovicic, M., & Rikalovic, et.al (2023).	Edge Computing Data Optimization for Smart Quality Management: Industry 5.0 Perspective	To optimize data without losing important information in big data.	Optimized small dataset will need further analysis and processing
Rani,S.,&Srivastava,G.et.al (2024).	Secure hierarchical fog computing architecture for industry 5.0 using an attribute-based encryption scheme.	Hierarchical fog computing architecture for smart energy- supplying systems	Developing data analytics and machine learning techniques to improve decision-making and strengthen security
Shkarupylo,V.,Alsayaydeh,J. A.J.,Yusof,M.F.B.,Oliinyk, A.,Artemchuk,V.,&Herawan, S. G.et.al(2024)	Exploring the potential network vulnerabilities in the smart manufacturing process of Industry 5.0viatheuseof Machine learning methods	Data capture, predictive maintenance, optimization, transparent decision-making, and proactive maintenance	Encryption methodologies like AES,DES and block chain to be utilized for ensuring the data security and privacy.
Ahmed,F.,Zhou,T.,Bilal,H., Islam, F. U., Ullah, R., &Vasilakos,A.V.et.al(2025)	Enhancing healthcare data integrity and access control using blockchain and industry5.0	CP-ABE encryption with decentralized IPFS storage and Ethereum smart contracts	scalability and ledger management will be tackled by enhancing interoperability with existing health record systems, improving the real-time detection of malicious nodes, and optimizing performance
Whang,S.E.,Roh,Y.,Song,H.,& Lee, J. G. et.al(2023).	Data collection and quality challenges in deep learning: Adata- centricaiperspective.	Challenges in data collection and quality	Data integration in network
Sahara,C.,&Rafiesta,A.M. et.al(2022).	Real-time data integration of an internet-of-things-based smart warehouse: a case study.	Data integration within the IoT-based warehouse	Needed to remove this human intervention in processes

Lymperis, D., & Goumopoulos,C.et.al(2023)..	Sedia: A platform for semantically enriched IOT data integration and development of Smart City Applications	data handling: gathering ,semantic labeling, storage, analysis, and presentation	Machine learning algorithms can be incorporated into the Application Layer of SEDIA to further process and analyze the retrieved data
Azaroiu, G., Androniceanu, A., Grecu, I., Grecu, G., & Neguriță, O. et.al(2022).	Artificial intelligence-based decision-making algorithms, Internet of Things sensing networks, and sustainable cyber-physical management systems in bigdata- Driven cognitive manufacturing.	Establish real-time connectivity between machines, sensors, and analytics platforms	Data architectures along with interoperable IoT frameworks gives full potential of cognitive manufacturing
Cukjati, J.et.al(2022).	IoT and Satellite Sensor Data Integration for Assessment of Environmental Variables: A Case Study	Data fusion strategy to generate the satellite- like images without needing to interpolate t	machine learning algorithms to better understand the relationship between IoT data and satellite sensor data.
Andronie, M., Lăzăroiu, G., Iatagan, M., Hurloiu, I., Ștefănescu,R.,Dijmărescu,A., & Dijmărescu, I. et.al (2023).	Big data management algorithms, deep learning-based object detection technologies, and geospatial simulation and sensor fusion tools in the Internet of Robotic	Integrating IoT devices using multiple-hop cellular networks, using a multi-level architecture with a blockchain-based approach	Safety issues such as framework privacy, authentication, heterogeneity, flexibility, and scalability are all addressed by the approach.

Approximately 35 billion Internet of Things (IoT) devices are online right now. It is predicted that by 2025,there will be between 80 and 120 billion internet-connected devices. This growth will lead to the creation of 180 trillion gigabytes of new sensor data that year. IoT sensor data comes from many different types of devices, connectivity protocols, and large data formats. This huge amount of data is not analyzed or integrated manually. For IoT developers, combining IoT sensor data presents a significant challenge. [25].

The study articles include a summary of knowledge gaps and the approaches used in earlier studies for interoperability and IoT data management A flaw in the study on IoT data interactivities and interoperability is the need for more comprehensive privacy protection strategies and centralized access control systems. Numerous tactics are employed, including semantic enrichment, specialized data fusion frameworks, and network performance optimization. Security, encryption, and semantic web technologies. Theoretical models and frameworks that are used include techniques and different types of data modeling procedures. Examples of theoretical models and frameworks used are the intricacy and diversity of data modeling techniques. This variability reflects the problems with IoT data integration and interoperability.

VI. RESERCHGAP:

After the reviewing of the proposed and previous works in the field of IOT network and data management the issues and challenges in the realm of data still open can be summarized as follows:

1. A small data set will need more analysis and processing.
2. Developing data analytics and machine learning methods to improve decision-making and increase security.
3. Encryption methods like AES, DES, and block chain are used to ensure data security and privacy.
4. Scalability and ledger management will be addressed by improving interoperability with existing health record systems, increasing real-time detection of malicious nodes, and optimizing performance.

5. Data integration in IoT networks needs to improve for efficient interoperability.

6. Needed to remove this human intervention in data management processes.

7. Addition od machine learning algorithms to the Application Layer of SEDIA to process and analyze the retrieved data further.Dataarchitecturesandinteroperable IoTframeworksunlockthefullpotentialof cognitive manufacturing.
8. Applicationofmachinelearningalgorithmstobetterunderstandtheconnectionbetween IoT data and satellite sensor data.
9. Safety issues like frame work privacy, authentication, diversity, flexibility, and scalability are all important in the field of data integration and need to be tackled.

V.CONCLUSION:

A transition to Industry 5.0 signals an important shift in the growth of the digital world across various sectors. In this context, it plays a crucial role in communication within the IoT network. The Internet of Things involves the connection between the physical and digital realms. Today, communication mainly occurs between people or between people and machines. However, IoT could lead to a remarkable future where machines communicate with each other. This study looks at current strategies and compares them. It includes various methods and algorithms related to interoperability and data integration within the IoT network. Additionally, it discusses new technologies like edge computing ,blockchain, and artificial intelligence that are changing how IoT data is integrated. The findings reveal that integrating emerging technologies has significant potential to produce vast amounts of data, yet challenges such as data collection, interoperability, and integration remain. This review emphasizes the importance of real-life implementation and prototype development. It focuses on essential advancements in data integration to improve technological use for intended applications, ensuring scalability and real-world impact. As Industry5.0connectsbillionsofdevicesandgeneratesterabytesofdata, reviewing the literature highlights the necessity for seamless interoperability in the IoT network. We aim to improve data integration techniques using a hybrid approach,incorporating datafeatureextraction.Thismethodwillallowforbettercontrolofdatatrafficoveranetwork, reduce latency and optimize bandwidth using AI algorithms. Furthermore, we plan to combine this approach with the CSI technique to enhance the reliability of data integration, which will promote efficient interoperability in the IoT network within Industry 5.0.

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