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Safeguard environmental health utilizing the synergy between internet of things, cloud computing and big data analytics

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***Abstract*---**To safeguard the health of the environment is a need of the hour. It will make the earth more sustainable for generations to come. Waste into Wealth is an apt approach towards optimum utilization of natural resources. Around the world, with industrialization and urbanization on the rise, the quantity of waste is increasing enormously. The composition of waste is also becoming more diversified. In many places, particularly in India, waste is being burnt or dumped, thus producing hazardous smoke or leeching into the soil and water. Implementing waste management schemes may involve mobilizing entire communities around the waste-issue. Innovative ideas on recycling waste are needed to make the earth green and sustainable, while offering simple solutions to turn waste into wealth. Internet of Things (IoT) is a worthy technology that can be used for these purposes. A waste management system based on synergy between IoT, Cloud Computing (CC) and Big Data Analytics (BDA) is proposed in this paper.

***Keywords*---**cloud computing, environment, health, internet things, recycling, waste management.

Introduction

Turning waste into wealth is a tremendous initiative towards an eco-friendly and green environment. We can implement appropriate waste management schemes which encompass all the stakeholders of the society. Everybody must be made

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aware about the significance of segregating waste, before disposing it. Such segregated waste can be collected and processed through methods like composting, bio-gas production, recycling, etc. We can manage the waste of households in an environmentally sustainable manner, without causing any harm to the local environment. It will also give employment to poor individuals and especially women from the marginalized sections of the society. This is an excellent example of sustainable development among the poorest. It has multiple effects on the community; environment protection and empowerment of the weaker sections.

Internet of things (IoT) (Al-Fuqaha et al., 2015; Borgia, 2014; Chen et al., 2014; Chettri & Bera, 2020; Lin et al., 2017; Navani et al. 2017; Siegel et al., 2018) is a practically feasible and down-to-earth technology that can aid us in converting waste into wealth. A smart city (Ahlgren et al., 2016; Anagnostopoulos et al., 2017; Mahmood & Zubairi, 2019; Montori et al., 2018; Shah et al., 2019; Sun et al., 2016; Zanella et al., 2014) refers to urban areas that employ various categories of electronic IoT sensors to collect data and utilize the knowledge extracted from the raw data to manage assets, resources and services efficiently. This includes data collected from citizens, devices, buildings and other assets. Such data is processed and analyzed to give intelligence inputs to the higher authorities. These insights are used to take appropriate decisions to manage community services like traffic, transportation systems, water supply, waste management, crime detection, schools, libraries and hospitals.

A survey of public health databases and the findings of the role of leadership in the health departments toward early prevention of COVID-19 is presented by (Bangkara et al., 2021). A review of the practices followed by the Halal Food Supply Chain (Almelaih & Omain, 2022) in the United Arab Emirates is discussed in literature. The impact of the system on consumer perceptions, trust and satisfaction are also discussed. A city generates around 2,000 to 4,000 tons of waste every day. If there is no recycling means employed, the waste will be used as landfill or dumped into water ways, causing large scale air and water pollution. Through proper initiatives, we can contribute to the cause of the environment by proper segregation and recycling of waste products. Recycling of waste has huge benefits and can save a lot of our natural heritage. According to experts, recycling of one ton of waste paper saves 17 trees and 28,000 litres of water.

Waste water discharged into sewage system by industries often contains suspended content like solvents, metals, organic pollutants, etc. Industries should not be allowed to dispose waste water like this, without adequate treatment. Investigation of biological treatment of waste water using activated carbon powder is presented in (Fares et al., 2018). An environmental planning model is proposed in (Miranda, 2018) for maintaining the quality of the surface water resources, utilizing their seasonal clinical variability. Samples are taken from the water bodies periodically, and statistical analysis of the sampled data is done through artificial intelligence based computational implementation. A meta-analysis is done on the factors that influence the participation in household waste sorting in developing countries in (Rousta et al., 2020). A survey of solid waste management and recycling strategies followed in different parts of the world is done in (Magram, 2011). The features that have to be incorporated in green buildings, their significance and contribution to sustainable environment are discussed in (Akshey et al., 2018). The significance of waste recycling is also discussed.

A review of IoT based solid waste management strategies are done in (Pardini et al., 2019). An IoT based reference model, a comparison of the existing systems and open research issues in solid waste management are also discussed. Smart factories based on Industry 4.0 and Industrial Internet of Things (IIoT) has become a hot research area. The concept has also growing interest among the academia and industry. A data transmission framework based on Software Defined Network (SDN) and edge computing in IIoT is also found in literature (Li t al., 2018). Management of IoT applications using web-based system is proposed in (Yao et al., 2015). Food waste management using IoT based smart garbage system and smart garbage bins (SGB) is proposed in (Insung et al., 2014). In this system the server uses a router and wireless mesh networks to collect food waste collection data. The SGBs use two categories of operations: stand-alone and cooperation-based operations for improving the energy efficiency and battery lifetime. Data is collected from the garbage bins using sensors and sent to the gateway using LoRa technology in (Bharadwaj et al., 2016). A complete IoT based automated system for efficient tracking, collecting, managing and monitoring of solid waste is proposed.

In (Ali et al., 2020), an IoT-based smart waste bin monitoring and municipal solid waste management system is proposed. The system is capable of effective waste collection and future waste generation forecast. A review of waste management systems proposed in literature is presented in (Abdullah et al., 2019). A new waste management system using IoT devices, smart bins and waste collection trucks of different sizes is also proposed. Remote telemetry units based tele-monitoring architecture is proposed in (George et al, 2015) for implementing secure E-Health applications, based on the convergence between IoT, CC and BDA. The research issues and emerging trends in the design and development of Cyber-Physical systems with relevance to the recent advancements in the IoT, CC and BDA technologies is discussed in (Kim, 2017). In (Cai et al., 2017; Wang & Alexander, 2016) the issues, challenges and future directions in the convergence of IoT, CC and BDA technologies are discussed. An IoT based architecture for waste management scenario is proposed in (Marques et al., 2019). The use of Constrained Application Protocol (CoAP), secure Hypertext Transport Protocol (HTTPS) and MQTT protocols for secure communication is presented. Performance evaluation of a waste management case study is also presented. Many waste recycling strategies are found in literature (Bartl, 2014; Humphrey et al., 1977; Lee et al., 2013; Rajendran et al., 2013; Vijay, 2017; Zikmund & Stanton, 1971). A review of the serious harmful effects caused to the health of the environment and living beings by the electrical and electronics equipments disposed as waste is discussed in (Beula & Sureshkumar, 2021). The e-waste management and recycling strategies that may be adapted in future for reducing the harmful effects on the environmental health are also discussed.

Materials and Methods

The CC technology provides a common workplace for IoT and BDA. IoT is a source of big data and big data technology is the data analytic platform. The inter-dependency between the three mutually exclusive technologies leads to information-based outcome orientation from product-orientation. If the IoT applications and BDA operate in isolation the full potential cannot be derived out of it. To arrive at better insights and take right decisions in time, blending data from various sources becomes highly essential. Thus, integration of IoT and BDA systems can provide better results quickly.

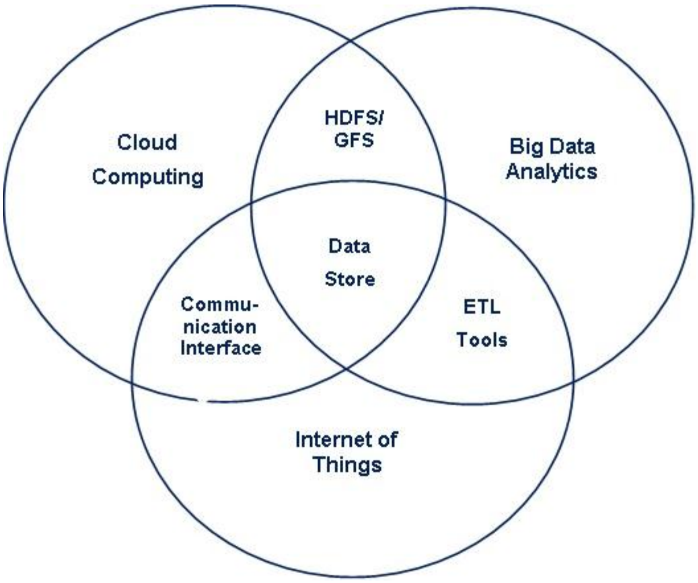

Figure 1. Synergy between BDA, CC and IoT

A simple illustration of the synergy between IoT, BDA and CC is shown in figure 1. Communication and networking technologies like LTE/4G/5G, Wi-Fi, Bluetooth/Zigbee and NFC lend suitable help in inter-operation between IoT and CC. Extract, Transform and Load (ETL) tools play a major role in the inter-dependency between IoT and BDA. Data Storage Frameworks like Google file system (GFS) or Hadoop distributed file system (HDFS) provide ample support for synergy between BDA and CC. A typical architectural framework illustrating the convergence between BDA, CC and IoT is presented in figure 2. The various components that constitute the various operations of the three mutually exclusive technologies and the technologies that leverage their inter-dependencies are illustrated in figure 2.

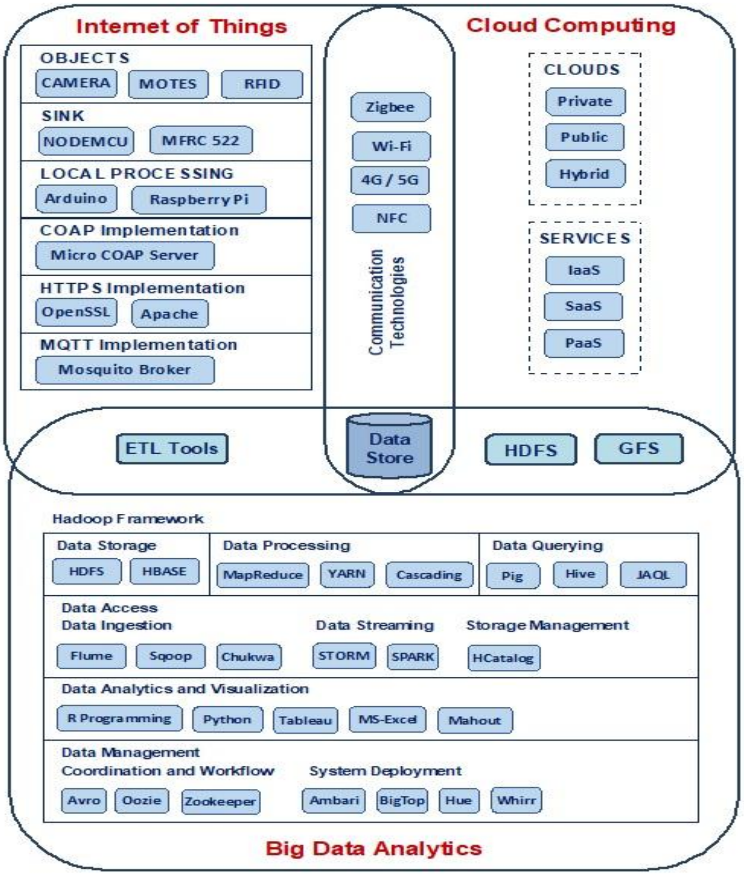

Figure *2.* Architectural Framework of Convergence between BDA, CC and IoT

The three technologies complement each other. IoT generates a large amount of data. CC provides a way to navigate the data by allowing data transfer through the internet. CC applications ensure adequate performance and scalability of data storage. The CC and IoT combination enable remote data storage and easy access. The BDA and CC combination enable deploying applications that can process and analyze data faster, provide precise business intelligence insights and take decisions, in time.

Results and Discussions

The proposed system is based on the convergence of IoT, big data analytics and cloud computing. The smart waste management system decides the type of segregations to be done for the waste collected from different locations and provide inputs for the appropriate recycling strategies to be followed. The architecture of the proposed system based on the synergy between BDA, CC and IoT technologies is presented in figure 3. The IoT sensors can be used to collect details about the type and quantity of the waste generated in different locations. Industry 4.0 and IIoT based systems can be used to implement segregation, recycling and disposal of waste. The IoT framework is responsible for data acquisition, waste collection, segregation, recycling and disposal.

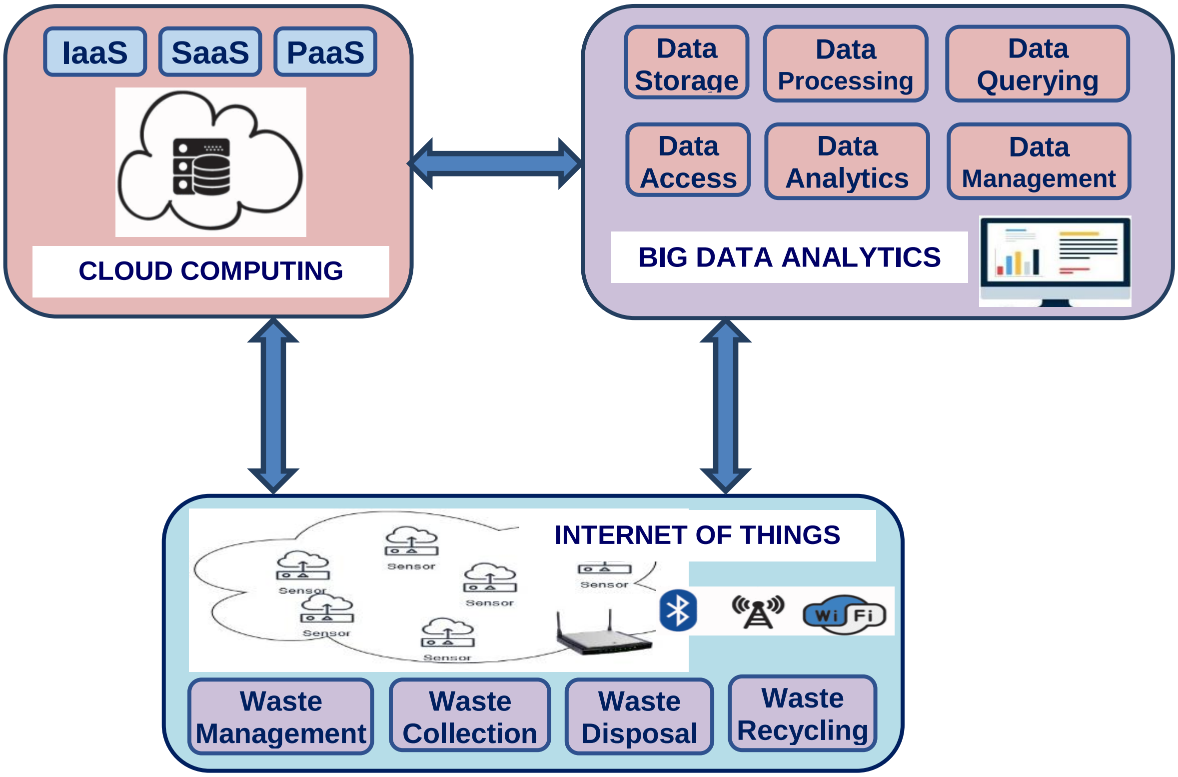

Figure 3. System Architecture

A data collection program is designed. A waste collection scheme is devised. The data acquisition system collects the details of waste collected. Such incoming data is stored in a way that will allow further modeling and reporting. The data acquisition regarding waste collection details are sent to the cloud over the Internet using the Message Queue Telemetry Transport (MQTT) protocol. Data from multiple sources are extracted, transformed, joined and loaded in a data store in a relevant and logical manner. The system checks for anomalies and unusual patterns also. The system performs wrangle of raw data before moving further into the modeling process. Then, the munged data is stored. Modeling and analyzing the data sets is done using statistical analysis and machine learning algorithms.

The actions carried out by the waste disposal system are based on the insights or intelligence derived from the collected data and the decisions determined by the BDA framework with able support of the CC framework. The BDA architecture takes care of deciding the strategies, optimizing process efficiency, correlation of operational efficiency, disposal and recycling strategies. The BDA subsystem may use machine learning algorithms for deciding the type of operations to be implemented. The categories of machine learning algorithms are supervised learning and unsupervised learning algorithms. Supervised learning may be used for labeled data and unsupervised learning may be used for unlabeled data. Classification and Regression are types of supervised learning techniques. Clustering and dimension reduction are types of unsupervised learning techniques. The flow chart that illustrates the operation of the proposed system that utilizes the benefits possible out of convergence of the three technologies is presented in figure 4.

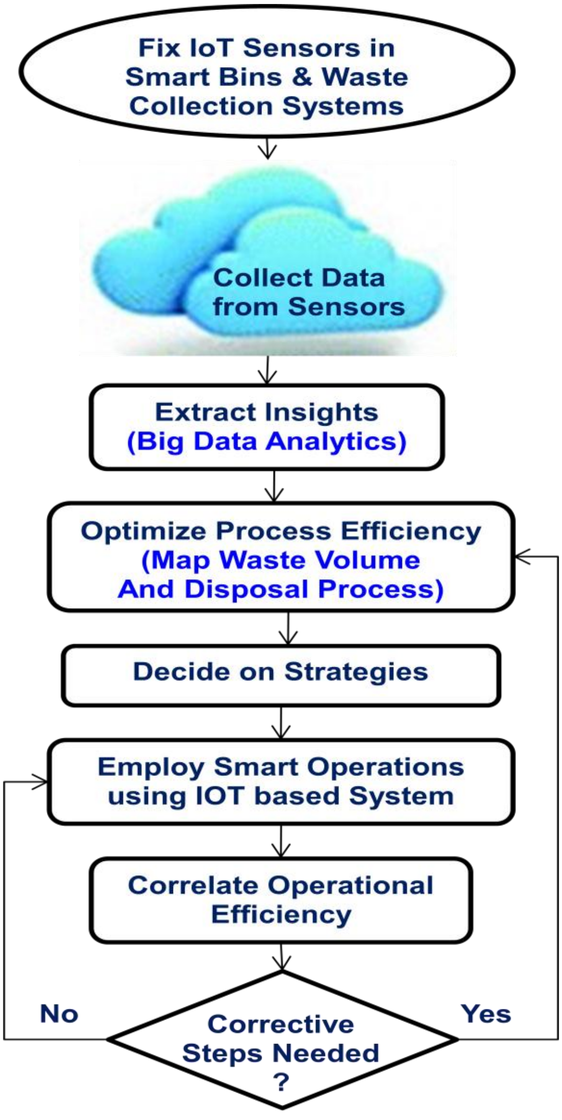

Figure 4. System Operation

Proper segregation and recycling of waste will lead us to the path of green and sustainable earth. Learning about conversion of recycled paper into useful products will create new local jobs, particularly for unskilled rural women. Waste paper can be converted into useful products like files, folders, pen stands, lamp shades, carry bags, stationary, etc. This encourages recycling of paper to ensure conservation of the precious resources; trees and water. Hand-made paper technology is a unique technology to recycle waste like cotton rags, denim materials and fibres into high quality handmade paper. Paper mills can save millions of rupees, every year by converting methanol, a polluting by-product into formaldehyde, a useful product.

Some women self-help groups utilize banana fibre and bark gainfully to produce disposable plates and bowls. Making drinking straw out of coconut tree leaves is another innovative idea. Laying roads using waste plastic has also been proved to be a successful idea. Slag and dust are waste products generated by steel mills. Slag can be used for manufacturing cement, vitrified steel and build roads. Bricks made out of the dust mixed with rice husk and other materials are stronger than conventional bricks. They are also sun-dried and need not be baked.

Organic manure could be used beneficially for crop production to minimize the problem of environmental pollution. Organic way of cultivation can be used to sustain the soil health and yield. Converting waste into wealth can deal with various issues like environmental protection, reduction of global warming, landfills, and garbage handling costs. It also improves green cover, ground water quality, general health, hygiene, and civic amenities. Thus, these strategies provide cost competitive raw materials to industries.

Conclusion

Providing grants and concessions to bio-gas plants, recycling stations, compost sheds and other environmental research institutes will have potential long-term impact on making the earth greener. Without any doubt, converting waste into wealth is a worthy idea, need of the hour and lead to optimum utilization of natural resources with social responsibility. Waste recycling will also protect us from global warming. Internet of Things is a comprehensive and practically feasible technology for real-time implementation of such applications. The convergence of Internet of Things, Big Data Analytics and Cloud Computing enhances the benefits and magnitude of decision support systems that may help implementing the waste into wealth strategy. The synergy between these technologies can provide new opportunities and applications in all the sectors. More funding by government agencies for sponsored research projects related to such innovative ideas will enhance constructive development. These strategies will safeguard the health of the environment and make life on earth sustainable, for more generations to come.

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