International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. 10, No.1 (Feb-2021)

http://dx.doi.org/10.12785/ijcds/100135

Management of WSN-enabled Cloud Internet of Things: A Review

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Received 2 Mar. 2020, Revised 30 Apr. 2020, Accepted 3 Aug. 2020, Published 8 Feb. 2021

Abstract: Internet of Things (IoT) is the networking of computer devices and objects to share information through the internet. The last seven years have witnessed great success in deploying massive cloud storage and computation resources to leverage IoT devices' limitations. However, IoT sensing device(s) such as Wireless Sensor Network (WSN) is still challenged with inefficient sensing data provisioning in real-time basis. Therefore, this paper investigates the existing algorithms developed by previous research to manage WSN to retrieve efficient and desired sensed data on the Cloud IoT paradigm. The background information is presented about the origin of WSN-enabled Cloud IoT and its current developmental stride. We identify and analyze how the algorithms can manage the WSNs to resolve the challenges mentioned above. Furthermore, we discuss how the algorithms are evaluated and validated by useful Quality of Service (QoS) delivery metric parameters. As stated in previous research, the future performance improvement of the algorithms, which pave the for future research directions, is also presented in this paper and ends with a concluding remark.

Keywords: Wireless Sensor Network, Internet of Things, Cloud Data Center, Quality of Service Deliver Parameters

1. Introduction

The integration of Cloud Computing and the Internet of Things (IoT) has revolutionized the deployment and usage of Information Communication Technology in recent times. Presently, it is used to provide on-demand sensory data resource(s) and application service in various fields such as healthcare, manufacturing industries, education, agriculture, and smart city. IoT is a network of interconnected things or device(s) which are embedded with sensors, software, network connectivity and related electronics for the retrieval and exchange of data from physical objects (e.g., environment, fridges, and vehicles) [1]. It is a framework that integrates the physical world and computer systems, enabling both to communicate and share information over an existing network (e.g., Internet) connectivity. For instance, a lightweight platform can be deployed in an individual's home to collect data from connected objects such as the fridge, electric lights, and heating systems [2]. The data obtained are transmitted through a private or public network to a computer server and other accessible storage devices. IoT device(s) generates a massive amount of data with various connotations and limited storage space, processing capability, and energy power source. On the other hand, the cloud massive storage resource and data-intensive computational tasks (e.g., data fusion and coordination capabilities) for achieving more excellent data quality and energy efficiency. Cloud computing is a service delivery model of dynamic, scalable and virtualized resources as through the Internet [3]. Therefore, integrating both Cloud and IoT can support IoT devices' requirements, which leads to the provisioning of new and exciting data resource(s) and applications to the end-users [4]. This is because the features of the cloud are utilized to resolve the limitations of IoT devices. The Cloud-enabled IoT infrastructure's immediate challenges are the massive data generated from heterogeneous, dynamic and seamless IoT devices [5]. IoT device(s) such as Wireless Sensor Networks (WSNs) are powered by battery energy that depletes within a limited operation period. These operations include sensing coverage, radio communication, data processing, and sampling. Therefore, there is a great need to conserve sensor nodes' energy consumption in the WSNs during operation. Previous research surveys on Cloud-IoT infrastructure mainly focus on a particular research domain such as the survey on applications and challenges of Cloud-IoT, an overview of sensor cloud infrastructure and a review on

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security management of Docker cluster in the cloud. Therefore, this research aims to explore and analyze the deployment of existing algorithms developed to manage WSNs for efficient provisioning of desired data on Cloud IoT infrastructure. Our contributions in this research are as follows;

- We present a piece of background information about the WSNs-enabled Cloud IoT's main components, its origin, and current developmental strides.
- We identify and analyze how the existing algorithms can manage the physical features of WSNs for efficient provisioning of desired sensing data on the Cloud IoT platform.
- We discuss the efficient quality of service delivery (QoS) metric parameters used to evaluate and validate the existing algorithms' performance.
- We highlight the challenges resolved, benefits and the limitations of existing algorithms that will motivate further research in this field in the foreseeable future.

The rest of this paper is structured as follows; Section II presents the background information of WSN enabled Cloud IoT. Section III discusses the research methodology adopted to actualize the current research survey understudy, while Section IV presents brief related research works in Cloud IoT. Section V comprises a detailed analysis of the existing algorithms, highlighting the issues they resolved, results (benefits) and future improvements in a tabular form. Section VI discusses the efficient QoS delivery metric parameters used to evaluate and validate the existing algorithms. Section VII contains discussion and concluding remarks.

2. BACKGROUND INFORMATION

Cloud and the Internet of Things are two different technologies that are presently making a new trend in the computing industry. The phrase "Internet of Things" was invented some two decayed ago by the founders of the MIT Auto-ID Center, co-headed by Kevin Ashton in 1999 and David L. Brock in 2001. Auto-ID is defined as any broad class of identification technologies used to automate, minimize errors, and improve efficiency [6]. Devices such as smart cards, barcodes, sensors, biometrics, and voice recognition are classified as Auto-ID technologies. However, Radio Frequency Identification (RFID) has been the dominant Auto-ID technology in use since 2005. RFID is a technology that enables computers to identify and track objects (e.g., raw materials and finished products) automatically as they flow from the production stage to the distribution center and ends in the shelves of shop outlets. It is mostly used in manufacturing industries and Courier services for identification and monitoring of goods on transits in real time basis. In that same year, Kevin Ashton stated that "IoT is considered as the extension of Radio Frequency Identification, in the form of amoeba in wireless computing world" [6]. IoT was formally introduced in 2007 when the International Telecommunications Union initially circulated the report on the subject. The Union categorically adopts a holistic method suggesting that IoT interconnect things (e.g., sensor devices) intelligently by labeling and curbing things using Wireless Sensor Networks (WSNs) and Embedded Systems. It is envisaged that in the year 2020, the development and adoption of WSN and smart sensor devices will increase to 50 billion on-demand. The primary function of WSNs is to capture and divulge live events, which are converted into data format can be processed and stored [7]. Consequently, cloud computing is an information technology business model delivered as a service through the Internet. Both hardware and software computing services are dispatched on-demand basis to end-users in a self-service manner with minimum service provider interference [8]. Cloud computing came into the limelight in the year 1959 by John Macarthy. The ideology of developing a time-shared computers that can allow the sharing of computing resources (e.g., applications and hardware) between two or more end-users via multi-tasking instigated the evolution of cloud computing. He further stated that computers should become a utility like the telephone services in the year 1961, which motivated Douglas Parkhill to base his research on utility computing's feasibility in the year 1966. His research results depict that the tendency for the actualization of utility computing services is not feasible. In 2004, Salesforce.com began to provide cloud services such as Software as a Service (SaaS) on the World Wide Web to end-users on a "pay-as-you-use" basis. Consequently, Google joined the trends in the year 2004 by offering free email services that enable end-users to send messages virtually to their loved ones irrespective of their geographical locations in the world. Also, Amazon introduces Elastic Cloud computing (EC2) that enables numerous end-users to pay and use applications dynamically, on-demand, over the Internet [9]. In the year 2010, Cloud Azure was introduced by Microsoft for the delivery of services to end-users. These cloud services comprise storage space, applications and hardware. Over the last five years, great successes have been achieved towards integrating Cloud and IoT Technology as both tend to complement each other. IoT sensing devices generate enormous data and are prone to limited storage resources, processing power, and energy. Therefore, the cloud offers a practical solution to leverage IoT devices' challenges by providing its virtually unlimited resource(s) storage space and high computational capabilities. Hence, “extending the scope of IoT to deal with real-world things for the delivery of new services in a large number of real-life scenarios” [10], which lead to the formulation of a new era in Information Technology, called Cloud-IoT. The new service paradigm includes Sensing as a Service (SaaS) for enabling virtual access to remote sensor data and Sensor Event as a Service (SEaaS) for distributing messaging services obtained from sensor event coverage. Furthermore, Ethernet as a Service (EaaS) for enabling virtual layer-2 connectivity to remote devices [11], and Video Surveillance as a Service (VSaaS) for providing ubiquitous access to recorded video and implementing complex analyses on the Cloud [12]. Fig. 1 depicts the architecture of WSN enabled Cloud-IoT infrastructure. According to Zhou et al. [13], Cloud-IoT infrastructure comprises four layers: Cloud Things service platform, Cloud Things Developer Suite, Cloud Things Operating Portal, and WSN. Sensory data requests obtained from end-users via the Cloud Things Operating Portal are deposited in the Cloud Things service platform, which is further dispatched to the WSNs to provide sensed data.

The sensed data obtained from the WSNs are retransmitted into the Cloud Things service Platform via a wireless communication channel (e.g., WiFi and 4G) for further processing. The Cloud Things service platform is a set of cloud services (IaaS) that provides hardware (e.g., servers, storage, and network) and associated software such as operating systems virtualization and file system as services [14]. It interacts directly with the WSNs and enables the collection, storing and retrieving of sensory data. Furthermore, a massive sensory data volume is processed and analyzed using the computational resources on the Cloud. Cloud Things Developer Suite is a conventional cloud service tool (PaaS) that leverages the development platform to design, implement, and deploy its Applications [15]. An example of service tools consists of Application Programming Interfaces (APIs) based on the open-source web. Cloud Things Operating portal is a cloud service (SaaS) that supports the distribution and handling of specialized processing services that comprise the discovery of WSN physical features and data intelligence [13]. WSNs are tiny low powered chips deployed to monitor a specific geographical area or the internal organs of humans. It consists of four essential components: the processing unit, sensor, communication, and power units [16].

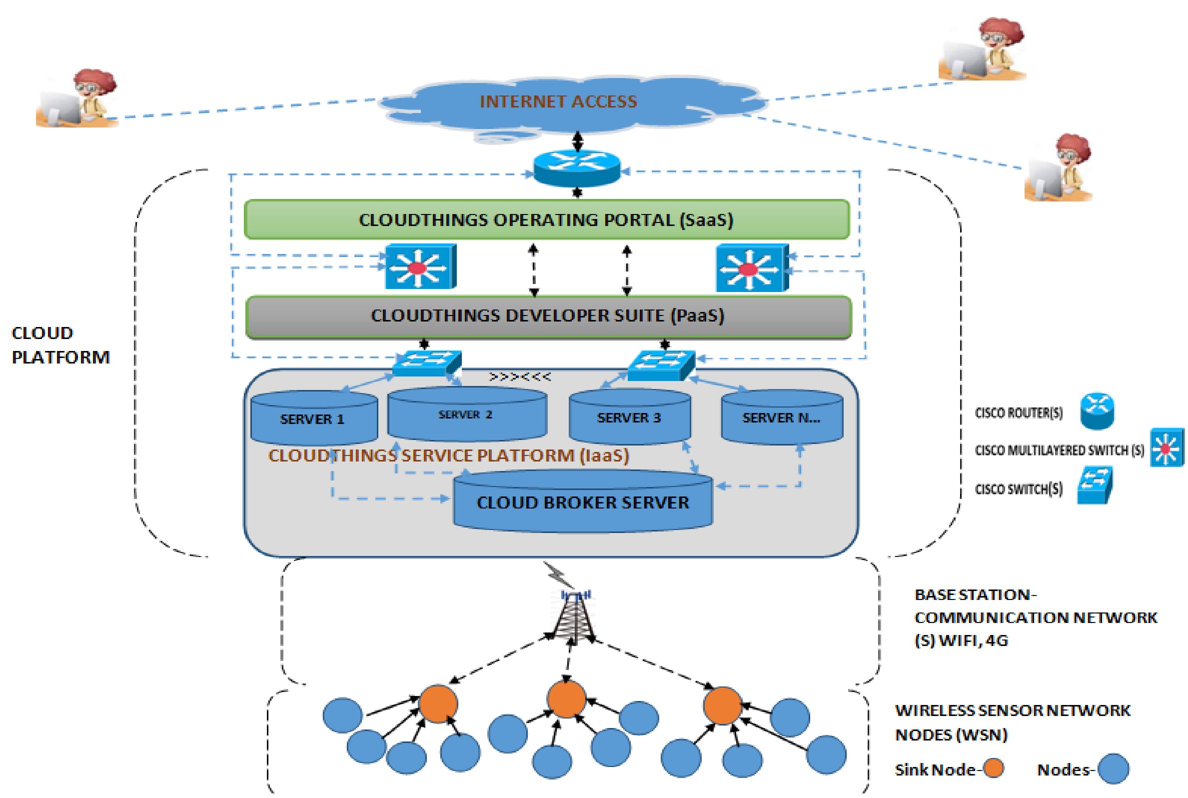

Figure 1. Architectural design of WSN enabled CloudIoT (Shows the different components that makeup the WSN-CLoudIoT Infrastructure)

3. RESEARCH METHODOLOGY

The methodology framework is utilized to conduct this research survey. The literature search covers contributions from 2012 to 2019, exploring the most appropriate databases to find the targeted articles. Fig. 2 denotes the total number of previous works of literature obtained to actualize this study's objectives. These databases include Elsevier, Springer, IEEE Xplore Digital Library, Emeraldinsight, IGI Global and ACM. The search queries that were utilized to retrieve relevant literature are ("Algorithms for WSNs in Cloud Internet of Things) and ("Sensory Data management in Cloud internet of Things). Numerous literature relevant and irrelevant to the current study were retrieved based on the search queries—resulting in a total of 106 candidate articles obtained from the initial search. Furthermore, literature published only in English and contained in conference proceedings, white papers and journals were considered. Each candidate article passed through some critical stage of scrutiny before they were selected, which are listed as follows;

- Assessing the title of the candidate articles and removing those that are not relevant to the current study.
- Reading the abstract and discarding those unrelated to the study (algorithms used for the management of WSNs enabled Cloud-IoT).
- Read the introduction and conclusion to assess the quality of the contribution, and discard if the contribution quality is low.

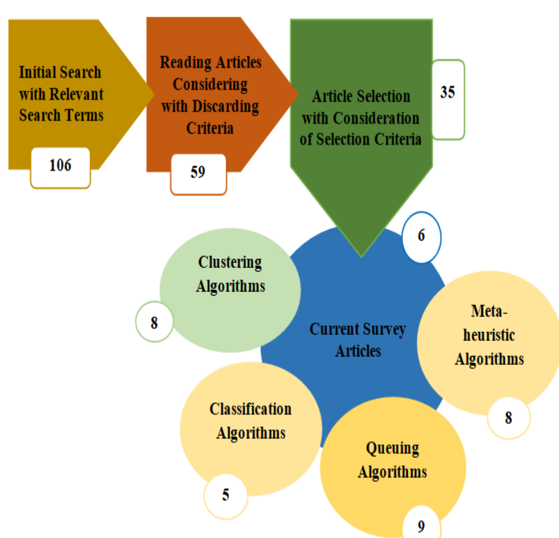

Figure 2. Research Methodology (Describing the steps taken to obtain related literatures in this study)

The parameters used for the assessment of quality contribution are based on the level of relevance about the existing literature with the algorithms deployed to manage WSNs-enabled Cloud-IoT infrastructure, soundness, credibility and writing quality. After which, a total of 30 articles are deemed to have passed the selection process as depicted in Fig. 2. Therefore, 30 articles were selected to actualize the research aim and the level of interest in utilizing algorithms for managing WSN's physical features and its sensed data in Cloud IoT infrastructure.

4. RELATED WORKS

This section summarizes the research work of existing survey papers on Cloud-IoT to determine its present developmental potentials and aid the problem formulation of the research under study. A survey on sensor cloud infrastructure is designed by [17]. It discusses the general overview of the sensor cloud platform about its definition, architecture, and applications. It also presents the existing challenges, solutions, approaches and future research scope. The investigation of IoT Trust Management is formulated in [18]. It analyses relevant literature articles on the trustworthiness of WSNs. The issues yet to be resolved are highlighted and proposing architecture for the overall Trust Management on IoT system deployment. A review on techniques and state-of-the-art research work in IoT data-centric perspective is presented in [19]. It discusses various data storage models, complex event processing, comprehensive searching techniques and data stream processing in Cloud-IoT. The current IoT technology investigation by considering its physical layer, application, and data layer is formulated by [20]. It also focuses on fifth-generation (5G) networks and semantic web for IoT infrastructure. Furthermore, [21] introduced a research survey based on the management of various cloud services such as analysis tools, applications, servers and virtualization. Consequently, [22] embark on reviewing a high-level conceptual layered architecture of IoT- Cloud enabled Fog computing from a computational viewpoint. The architecture emphasizes issues related to cloud computing, fog, sensors/actuators and how they can be managed. The current research survey understudy aims to explore the existing algorithms deployed to manage WSNs physical features and its huge amount of sensed data in the Cloud-IoT platform, as opposed by previous research surveys in this field. The algorithms are classified by their processes namely Clustering, Classification, Queuing and Meta-heuristic.

5. ANALYSIS OF THE EXISTING ALGORITHM

It is imperative to retrieve timely data from multiple WSNs to be transmitted onto the cloud data center on a real-time basis. The algorithms developed by previous researchers for managing the physical features of the

WNSs and their heterogeneous sensed data are presented in this section.

A. Clustering Process

The template is designed so that author affiliations are not repeated each time for multiple authors of the same affiliation. Please keep your affiliations as succinct as possible (for example, do not differentiate among departments of the same organization). This template was designed for two affiliations. It is an unsupervised learning process that extracts hidden patterns and structures from the dataset. Unlike classification with some prior knowledge to strategize the partitioning operation, clustering does not have any pre-knowledge about the strategy to be used for the extraction process. It aggregates the data into groups based on their similarity features and a standard structure and the data points in various dissimilar clusters [22]. However, the "fundamental challenge of clustering process or technique is based on its effectiveness in dealing with dynamic and heterogeneous sensing data partitioning to find optimal solutions for NP-hard problems" [23]. Therefore, it is mandatory to implement a suitable clustering algorithm that can effectively address the targeted problem, for instance, to solve combinatorial optimization sensory data in the Cloud-IoT infrastructure, where the computational processes become critical.

Implementing a clustered base algorithm to obtain sensing data from multiple WSNs is presented in [24]. The sensing data retrieved are transmitted to a local database server located close to the WSNs to minimize sensor network nodes' energy consumption. Consequently, the database server is decolonized and distributed to transparently and efficiently transmit the sensing data to the cloud data center. The clustering algorithm is responsible for abstracting sensing data and actuation resources from WSNs. It also facilitates the connection of virtualized sensor network nodes on the cloud with the Autonomic enforcer's support, enabling the physical features of the WSNs to be accessed virtually by end-users. A resource and bandwidth-aware wireless sensor (capsule) video summarization algorithm on mobile phone enabled cloud-based infrastructure is proposed in [25]. Wireless capsule sensors are digested in the form of a pill-sized capsule that allows the diagnostic image monitoring of the entire gastrointestinal (GI) digestive tract in humans. It is composed of a tiny camera, light source, radio frequency transmitter, and batteries. It pushes a large volume of video frames obtained into mobile phones where they are pre-processed. The summarization algorithm is responsible for extracting relevant video frames from multiple frames by eliminating irrelevant video frames. This is done by comparing the frames using Jeffrey-divergence between the histograms color and inter-frame correlation of the adjacent video frames' color channels to discover the irrelevant video frames. The un-useful video frames are eliminated by extracting multi-fractal texture features using the ensemble-based clustering process. The actual video frames obtained are offloaded to the cloud data center for the onward process. Furthermore, Liu [26] proposed a Two-step K-means Clustering (TKMC) algorithm to cluster the image sensed data retrieved from IoT devices into two categories namely, Blurry and Clear Image. Thus, the blurry images are discarded while the clear Images await further processing. Clear image sensed data is further segmented into two categories, namely foreground (Containing the actual image data) and background (containing un-useful image data), by utilizing the watershed segmentation function at the edge (i.e., clusters of servers) layer. This is done by extracting the clear images and removes the background image leading to the actualization of the foreground (desired) image.

Productive Periodic-frequent Pattern-growth (PPFP-growth) algorithm is proposed in [27] to reveal all the productive-associated regular, frequent patterns from sensed data. It further removes uncorrelated periodic data from the sensed data sets. In simple words, it can filter a large volume of periodic patterns to discover only the correlated ones, by utilizing large chunk of memory for storing only the transaction information (correlated) at the tail-end of each branch. Table I illustrates the clustering algorithms' comparison highlighting the challenges resolved and achievements obtained, together with their feature improvement.

Conversely, [28] proposed a Map-reduced Productive periodic-frequent Sensor Patterns (PPFSP-H) mining algorithm for efficient mining of the complete set of productive periodic-frequent sensor patterns among the discovered patterns from body sensor nodes. This is actualized by utilizing the pattern growth inspired function and a tree structure to identify and chronologically associate similar frequent patterns, reducing the cloud server's computational memory usage while improving the processing time. The development of a framework that queries massive audio/visual data obtained from an inbuilt mobile phone sensor camera device(s) is presented in [29]. Likewise, [30] implement a clustered-tree algorithm to reduce the energy consumption of visual sensor networks by considering their spatial-temporal coverage but unable to address the heterogeneous sensed data storage and the energy consumption challenges of the WSNs. However, the framework media query process comprises Pareto distributed/query volume, Exponential distribution, and Half-gaussian distribution algorithms. They are implemented to minimize the energy consumption of visual camera sensor networks and the billing cost of accessing visual sensory data from the

TABLE I. COMPARISON OF CLUSTERING PROCESS

S/N	Algorithms				
	Article Title	**Algorithm Name**	**Challenges**	**Achievement**	**Future Improvement**
1	Combining Cloud and sensors in a smart city environment [24]	i) Clustering Algorithm	The high rate of energy consumption in WSNs	Minimizes energy consumption	To deploy more efficient Filtering and Aggregation technique on sensory data
2	Mobile-cloud Assisted Video Summarization framework for Efficient Management of Remote Sensing Data Generated by Wireless Capsule Sensors [25]	i)Summarization Algorithm ii)Ensemble clustering iii) Multi-fractal Texture Technique	Elimination of redundant video sensed frames, determining useful and un-useful video sensed data	Conserve the wireless capsule sensors energy consumption	To resolve the problem of Management of multi-objective optimization for the efficient provisioning of sensory data in Cloud-IoT.
3	A new deep learning-based food recognition system for dietary assessment on an edge computing service infrastructure [26]	i) Two-step K-means Clustering (TKMC) algorithm	Over fitting issues due to massive data	Improved clustering accuracy with reduced response time	To develop a mechanism that will speed up the computation process.
4	Mining productive-associated periodic-frequent patterns in body sensor data for smart home care. *Sensors* [27]	i) Lagrangian Productive Periodic-frequent Pattern-growth (PPFP-growth) algorithm	Usage of energy Filtering frequent data patterns from huge volume of sensed data	Shortest path route to Enhanced clustering process dud tot eh removal of recurrence data pattern from the data set.	To enhance it to a gene To develop a technique for resolving missing data issues.
5	Mining of productive periodic-frequent patterns for IoT data analytics [28]	Productive periodic-frequent Sensor Pattern algorithm	The global search space of data pattern and the failure to explore the actual correlation between data.	Improved clustering accuracy while reducing memory usage and computation time	The implementation of a technique for improving accuracy while resolving missing data issues.
6	Media Query Processing for the Internet-of-Things [29]	i) Pareto Distributed-query Volume Algorithm ii) Exponential Distribution Algorithm iii) Half-Gaussian Distribution Algorithm	trade-offs in the energy consumption and Billing cost Issue	Reduction of billing cost for provisioning of sensory data by providers, and minimizing energy usage	To enhance the expected performance under a broader range of parameter settings, using variations in the analytic modeling.
7	Energy Consumption of Visual Sensor networks: Impact of Spatail-Temporal Coverage [30]	i) Clustered-tree Algorithm	Energy consumption problem of sensors with regards to their spatial-temporal coverage	Energy usage is conserved by limiting the sensing coverage	To adopt a mechanism that will efficiently manage the huge volume of sensed data in the cloud platform.
8	Federated Internet of Things and Cloud Computing Pervasive Patient Health Monitoring System[31]	i) Data Clustering/Classification Algorithms ii) Fuzzy Data Fusion algorithm	Provisioning of real-time sensory data constraints and depletion of sensor networks lifetime	Minimize bandwidth transmission rate of sensor networks and improve battery lifetime	Privacy and Security Features are to be developed upon in the future as stated by authors.

Table I. Shows the different types of Clustering and Classification algorithms for resolving the issues related to data redundancy generated from WSNs for the provisioning of meaningful and useful data in CloudIoT Infrastructure. It shows the results of the issues solved as well as improving the performance of the algorithms in future work billing cost of accessing visual sensory data from the Cloud-IoT infrastructure. Additionally, analytic conditions were put forward to optimize the device(s) energy consumption and billing cost. This is done by determining the period at which sensing devices are in idle state. Sensed data are not generated during the idle state, which attracts minimum or no cost from cloud providers. Also, the time frame at which the sensing devices are in an active state (capturing audio/visual data) are monitored not to exceed the stipulated limits specified. Therefore, avoiding excessive energy usage by the sensors and the billing cost involved in storing and quarrying (processing) the sensed data generated. Implementing a pervasive Cloud-based WSNs infrastructure for remote monitoring of patient health in their respective homes is presented in [31]. It utilizes data clustering method to process sensing data retrieved from WSNs. Each sensor in the WSNs is capable of pre-processing by filtering the data (such as blood sugar, breathing, and glucose level as well as pulse oximetry and ECG rate) before dispatching them to a personal server via a blue tooth communication link. The clustering algorithm aggregates the sensed data, which triggers the alarm signal to notify the authorized patient and emergency healthcare personnel to access sensed data on the server on a real-time basis. The sensing data are also dispatched to the cloud for further processing and analysis. Moreover, the fuzzy-based data fusion algorithm is adapted to extract significant sensed data while discarding redundant ones at the local server located close to the WSNs. Hence, to conserve sensor nodes' energy usage and improve the bandwidth transmission rate between the WSNs and the cloud platform.

B. Classification Process

Classification is a supervised machine learning process that assumes some prior knowledge to guide the partitioning operation to formulate a set of classifiers to represent the best distribution of patterns [32]. Furthermore, the classification technique is design to utilize labeled and unlabeled data during the classification process. The labeled data set is mainly used to train the classifier, such as the prediction function, while the classifier classifies the unlabeled data. The research work in [33] proposes a QuadTree Decomposition (QTD) algorithm for the partitioning of Multimedia sensed data (e.g., pictures) array. The sensed data are classified into two-dimensional matrixes of varying sizes (MBs), which are processed to avoid distortion reduction for each MB. It further prioritizes the MBs based on the outcome of their distortion reduction. The large flat area with multiple pixels is assigned with minimum large MBs, while the high-frequency edges with a minimum number of pixels are assigned with a large number of small MBs. Consequently, [8] develop a constraint programming-based backpropagation algorithm to select the best route path to transmit sensed data from desired sensor nodes in the WSN. Hence, it reduces data packets' correlation between the selected desired nodes and inactive nodes, leading to enhanced accurate data classification. Furthermore, missing data are recovered from the inactive sensor nodes with the backpropagation technique's support. Also, [34] proposed a Discrete Wavelet Transform (DWT) algorithm to reduce excessive noise from sensed data signals to obtain relevant data signals. It removes the wavelet coefficients that contribute immensely to the noise from the signal. The relevant signal is retrieved by decomposing the sensor signals at various levels, after which vectors of coefficients are produced from each level. Therefore, the coefficient with the most wavelet is selected to reconstruct a new signal. A Collaborative-filtering-based Multi-criteria Matrix-based Integration (MCMLI) algorithm is developed in [35]. It determines the cohesive user-item subclasses for each criterion from sparse sensed data and forecasting the interests of users for each criterion accurately. Firstly, a user-item matrix is divided into a set of cohesive user-item subclass matrices, which are organized with correlated users and items for each criterion. This process is repeated until the subgroups accommodate all elements of the given user-item matrix. After which, user ratings on new items for each subclass are predicted. The predicted results are fused to make recommendations for users. Conversely, [36] introduced a Semantic Web Annotation-based Complex Event Processing (SWA-CEP) algorithm for the processing of IoT sensing data at gateway platforms. The SWA filters incoming sensor readings to discard irrelevant data with the support of its filter rule method. Then, the CEP processes the relevant sensed data by tagging them with shared vocabularies based on event rules. Hence, to facilitate the classification of the annotated relevant data into three types of events (normal, warning and critical level), they can be easily identified by higher-level applications and services.

Table II illustrates the comparison of classification algorithms deployed by previous researchers in this field. It comprise of the titles of previous researches based of classification processes and itemized the algorithms deployed to resolve the highlighted issues. Furthermore, it contains the benefits of the algorithms to with their weaknesses, which can be considered as future research directions in this field. Observation from the tables shows that the existing algorithms actually improve the performance of sensory data management by resolving the intending issues. Also, weakness of the research work in [33] was not specified in the literature. However, the other researches duly stated out the weakness of their proposed algorithms which are vividly itemized as denoted in the table. Observations also show that some of the algorithms were implemented at the cloud SaaS platform and the gateways. Consequently, the other ones were implemented in the cloud broker service layer.

TABLE II. COMPARISON OF CLASSIFICATION PROCESS

S/N	Algorithms				
	Article Title	**Algorithm Name**	**Challenges**	**Achievement**	**Future Improvement**
1	Multimedia Sensing as a Service (MSaaS): Exploring Resources Saving Potentials of at Cloud-Edge IoT and Fogs [33]	i) Quad Tree Decomposition (QTD) algorithm	High energy consumption during retrieval and sensed data from IoT sensor devices.	Conserve the energy usage of sensing Devices during sensed data retrieval sensed data.	NoT Specified
2	Cloud-Assisted Data Fusion and Sensor Selection for the Internet of Things [8]	i) Constraint Programming-based Back-propagation (CP-BP) Algorithm	The issue of missing data that emanate from the high correlation of data between the inactive and active sensor	Enhances accuracy due to the proper selection of desired sensor nodes for retrieval of actual sensed data and the recovery of missing data.	To extend the proposed algorithm for real-time deployment. Also to integrate adaptive sampling rate into our current results, as well as investigating multi-sink scenarios.
3	Insights Into IoT Data and an Innovative DWT-Based Technique to Denoise Sensor Signals [34]	i) Discrete Wavelet Transform (DWT) algorithm	The issue of excessive noise in sensed data signals.	Improves sensed data signal with 90 % accuracy of the reconstructed signal.	To enhance the proposed technique for forecasting purposes and to evaluate its accuracy by comparing the final decision-making process in realistic scenarios.
4	Multi-criteria matrix localization and integration for personalized collaborative filtering in IoT environments [35]	i) Collaborative-filtering-based Multi-criteria Matrix localization and Integration (MCMLI) algorithm	Sensed Data-sparsity problem retrieved from users feedback	Improves recommendation accuracy.	Plan to develop a Bayesian non-parametric based matrix localization method to improve the performance of MCMLI.
5	Event-driven and semantic-based approach for data processing on IoT gateway devices [36]	i) Semantic Web Annotation (SWA) algorithm ii) Complex Event Processing Algorithm(CEP)	High usage of computational resources, traffic bottleneck, and ineffective classification process.	Conserved computational resources and enhances transmission bandwidth rate from the gateways to the cloud. Also, enhances classification accuracy with response to time.	To investigate load balancing algorithms for managing the distribution of edge computing tasks based on resources available at the gateway level.

Table II. This table highlights the problems solved by the existing algorithms that utilize classification process to manage the sensor devices and their data in WSN IoT-based Cloud infrastructure.

C. *Queuing Process*

Most queuing algorithms are based on evaluating the network feedback, based on network traffic congestion detection and taking precautionary steps to adjust the output source by minimizing the congestion window [37]. However, over-allocation of resources to be transmitted over a network channel, without considering the effect of buffers, can lead to traffic congestion and depletes the entire Cloud-IoT network performance. Fig. 3 depicts queuing characteristics algorithm. The development of a tailing dam monitoring and alarm systems-based Cloud-IoT is presented in [38]. Tailing is the remains of the milling process deployed to extract required metals from mined ores or cleaning of calm. The conventional monitoring system deployed for tailings monitoring is time-consuming and relies on humanitarian assistance to manually compute tailing operational parameters. However, the implemented Cloud IoT based tailing dam

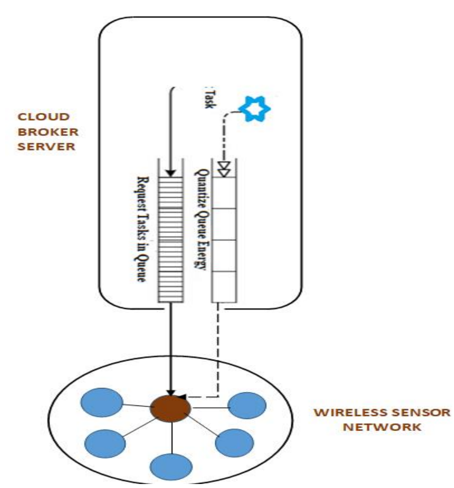

Figure 3. Design of Queuing and Control algorithm (Illustrating how tasks are scheduled on a queue waiting execution)

monitoring and the pre-alarm system adopted the Regulatory based Control algorithm to resolve the conventional system's flaws. Wireless sensor nodes (drill-hole pressure and water level, and the deformation sensors) are embedded at the tailing dam site to obtain data about the tailing dam's physical condition. Furthermore, the sensor nodes are connected via Wi-Fi to their respective sink node, which has an in-built microprocessor and transceiver. The sink node transmits data to a network layer that is saddled with the responsibility for receiving packets of data from multiple WSNs and dispatches its contents into the cloud to be processed into useful information. With the information in hand, the dry beach length and the top elevation levels are constantly monitored to prevent flooding of the tailing dam with the pre-alarm parameters' support. The Regulatory-based Control algorithm is also saddled with the responsibility to notify any unforeseen danger. For instance, if any sensor value is above the safety pre-alarm value, it triggers the alarm system for urgent response measures to be taken in order to prevent disaster. A multi-sensor gateway high-performance scheduling model of a cloud-enabled A sensor platform for a smart living is proposed by [39]. Scheduling and catching sensed data are executed by unifying 0-1 programming and periodic task algorithms before they are dispatched to the cloud. Earlier work in [40] introduces polynomial-time contestant-speed feasibility and weight maximization variant algorithms based on a communication-centric scheduling scheme. They are deployed to test for the multi-sensory platform and determine a subset of sensor request tasks with maximum weight that can be scheduled. The aforementioned communication-centric scheduling scheme only focuses on the media access control (MAC) layer, which is posed with the complexity to find the optimal channel for scheduling multiples of sensory request tasks. However, the multi-sensor gateway high-performance scheduling model is composed of a manager, primary manager (MM), a cache manager (CM) and the scheduling manager (SM) servers. The primary manager provided a unified input and output framework for retrieving sensed data from WSNs and dispatched them to the cache and scheduling managers. The cache manager stores sensed data temporarily and trigger the scheduler manager to schedule sensed data by executing the 0-1 programming algorithm based on end-user requests.

The development of a Cloud-IoT enabled architecture is presented in [41]. It is based on the utilization of HyperText Transfer Protocol (HTTP) and Massage Queuing Telemetry Transport (MQTT) protocols for optimal performance. The proposed architecture is composed of multiples of WSNs, router, and cloud data centers. The WSNs are embedded in the environment and transmit their sensed data via a router device to the cloud. The cloud data center consists of HTTP and MQTT servers. MQTT server is regarded as the master node, initiating other servers (e.g., HTTP server) as slaves. It uses its broker-based protocol to publish and subscribe to message transmission, enabling efficient interaction between the WSNs and end-users. It also maintains a steady use of Transmission Control Protocol (TCP) connection between the end-users and the WSNs, to improve real-time service performance and reduce the energy consumption of WSNs. Furthermore, it guarantees reliability by deploying three quality of service (QoS) mechanisms: acknowledgment/handshake, hypertext transfer protocol, and the Cloud-IoT platform. The acknowledgment and handshake mechanism are used to ensure that all requests are successfully delivered to prospective end-users. The hypertext transfer protocol utilizes a web-enabled application framework to interact with clients via a request-response cycle. Subscribed clients can easily access the HTTP server resources by sending a request via mobile phones. Upon receiving a request, it is acknowledged, processed, and the results retransmitted back to the clients. The Cloud-IoT platform uses a database cluster mechanism called redis2 to store data. Redis2 cluster with multiple Redis nodes is configured in the Cloud-IoT to enhance the database's reliability and the entire system. The implementation of an edge router deployed to interconnect multiple of WSNs is presented in [42]. Regressive Admission control (REAC) and Fuzzy Weighted Queuing (FWQ) algorithms are implemented in the edge router to monitor unforeseen changes in the network quality of multiple WSNs. Also, to provide efficient and stable network performance by optimizing network path and resources. The FQW algorithm improves the traffic path for the smooth transmission of sensed data from the WSNs to the edge router and cloud. On the other hand, the REAC algorithm manages the performance of end-to-end networks, supported by the real-time QoS monitoring algorithm for the prevention of malicious traffic or denial of service attacks on the networks, during data transmission phase. An intelligent queuing algorithm is also implemented in the edge router to prevent traffic congestion and efficiently allocate resources to specific traffic flows.

A Real-Time Adaptive Algorithm based on the Markov decision process (MDP) for Video Streaming over Multiple Wireless Access Networks based mobile Sensing Cloud platform is proposed by [43]. It utilizes parallel computation for real-time video streaming that enables mobile sensing devices to offload computation, communication, and resource-intensive operations to the cloud. On the other hand, the cloud is responsible for the computational processes and storing of Real-time Video Streaming (RTVS) frames. It is also saddled to forward processed RTVS to mobile sensor devices based on end-user requests, leading to the reduction of energy usage and optimal performance of the mobile devices. Also, more memory space is conserved to speed up other processes that run on mobile sensor devices. Conversely, [44] proposed a Secondary Exponential Smoothing (SESM)

Prediction algorithm for processing sensed data retrieved from WSNs. SESM monitors the sensed data traffic between WSNs and gateway to determine if there are numerous or limited sensory data obtained from sensor nodes. The sensor node is compromised when the observation result shows that sensed data traffic is below or above the expected acceptable benchmark at a particular time interval, which the network manager prevents. After this, the sensed data are filtered to obtain the actual data within the targeted threshold of the accepted benchmark range. The ones within the benchmark range are discarded while the actual sensed data are transmitted to the cloud for onward processing. The cloud gateway is saddled with the responsibility to compress end-users requests and decompress (end-user sensed data) sensed data received. Therefore, it minimizes packet loss due to network traffic and dispatches them into the cloud for further processing. The Efficient Power Saving Scheduling algorithm based on dynamic AID allocation and Compressed Bitmap algorithms is presented in [45]. Thus, to reduce sensor metering devices' energy consumption by successfully scheduling the uplink and downlink traffic metering on the internet. Similar research work in [46] presented a power-saving with Offset Listening Interval algorithm to avoid collision by controlling the station wake-up time with the computed offset. However, the efficient power saving scheduling algorithm is enhanced to provide more lifetime to STAs battery of multiple WSNs, by utilizing the features such as small payload, low duty, and collision resolution technique. It also allows the STAs batteries to be allocated to the average service duration leading to STAs uninterrupted services. On the other hand, the Compressed Bitmap algorithm is adopted to reduce the communication overheads between the WSNs and cloud by compressing sensed data with similar features. Table III below shows the complementary information about the existing algorithms that utilize the queuing process.

TABLE III. COMPARISON OF QUEUING PROCESS

S/N	Algorithms				
	Article Title	**Algorithm Name**	**Challenges**	**Achievement**	**Future Improvement**
1	The internet of things (IOT) and cloud computing (CC) based tailings dam monitoring and pre-alarm system in mines [38]	i) Regulatory-based control algorithm	Monitoring of tailing dam site	Improves monitoring and pre-triggers alarm system to notify unforeseen danger	Unable to consider the tradeoffs between energy efficient of WSNs and Quality of data transmission, which has to be resolved in future work.
2	A high-performance scheduling model for the multisensor gateway of cloud sensor system-based smart-living[39]	i) 0-1 programming algorithm ii) Periodic algorithm iii) Cache Technique	Optimal channel for scheduling multiple sensor requests and an NP-hard problem for optimizing scheduling on multiple-hop	Efficient channeling of numerous sensor requests and improves the allocation of a sensor node for task execution	To Consider the overhead from application preemption and prioritization of sensor nodes for the performance of sensory request tasks.
3	Algorithms and complexity for periodic real-time scheduling [40]	i) Polynomial-time Constant-speed Feasibility Algorithm ii) Weight Maximization Variant Algorithm	Determination subset of sensor request tasks for scheduling	Multi-sensor request task was scheduled optimally based on the magnitude of their weight	To address the issue of a subsetof the sensory request tasks to be scheduled with minimal profit, by maximizing profit and optimal scheduling of multi-sensor tasks.
4	Internet of things Cloud: Architecture and Implementation [41]	i) Hyper Test Transfer technique (HTTP) ii) Message queuing telemetry transport (MQTT) technique	Reliability of sensory data transmission and management of physical sensor nodes	Improves transmission of reliable sensed data and minimizes energy consumption of physical sensor nodes	Security and Privacy issues to be considered in future work.
5	An Adaptive Edge Router Enabling Internet of Things [42]	i) Regressive admission control (REAC) algorithm ii) Fuzzy weighted queuing (FWQ) algorithm iii) Intelligent scheduling queuing algorithm	Monitoring network performance changes the prevention of malicious traffic	The transmission route path is Improved leading to enhanced bandwidth communication rate and efficient allocation of sensory resources.	Fusion of numerous algorithms for enhancing the performance of WSNs resources used for the servicing of applications.

S/N	Algorithms				
	Article Title	**Algorithm Name**	**Challenges**	**Achievement**	**Future Improvement**
6	Design and implementation of a novel service management framework for IoT devices in the cloud [43]	i) A real-time adaptive algorithm based on Markov Decision Process (MDP)	processing of video stream from multiple WSNs	Improves processing and efficient delivery of processed sensed video stream to consumers	Allocation of sensing resources based on scheduling approach for segmentation of video stream data in various surrogate modes and the forecasting of available bandwidth for streaming
7	A novel sensory Data Processing Framework to Integrate Sensor Networks with Mobile Cloud [44]	i) Secondary exponential smoothing (SESM) prediction algorithm	Monitoring and prediction of data traffic	minimizes data traffic congestion resulting in minimal data packet loss during transmission	Not Specified
8	An Efficient power saving polling scheme on the internet of energy [45]	i) Dynamic AID allocation algorithm ii) Compressed bitmap algorithm	Uplink and downlink traffic metering control	Reduced communication overhead and prolong the lifetime of WSNs Batteries	To manage WSNs data resources under ultra-dense networks, considering the congestion channelingto handle multiple access points procedure.
9	Power Save with Offset Listen Interval for IEEE 802.11ah Smart Grid Communications [46]	i) Offset Listening Interval Algorithm	Collision offset problem between sensor nodes	Avoid collision by controlling the station wake-up time with computed offset prolong the lifetime of sensor nodes	Not Specified

Table III. This table shows the algorithms that adopted the queuing process for the scheduling of sensory request tasks and sensor nodes for efficient dissemination of sensory data in the Cloud-IoT infrastructure. It also shows the results of the problems resolved and future improvement on the performance of the algorithms.

D. Meta-heuristic/Hybrid Process

Meta-heuristic is a strategy that makes some modifications in the heuristics to give better solutions in local search optimally [47]. They deliver suitable substitution between the highly-rated solution and computing time for resolving complex problems. Solutions obtained from heuristic methods are usually caught up in a local minima problem, which is resolved by the deployment of meta-heuristic algorithms. Consequently, meta-heuristics are often implemented to determine the best solutions from among multiple possible ones. However, they do not ensure that the best will be actualized in some instances. In most cases, they efficiently determine a solution close to the desired one. The hybrid process combines two or more algorithms to resolve a specific problem [48]. This is done either by selecting one of the more suitable algorithms or swapping them throughout the execution process. A task execution framework called Task-Alloc for Cloud-enabled WSNs is developed in [49], to reduce energy consumption usage of newly added user applications. It enables the selection of desired sensor nodes in the WSNs for sensed data retrieval and allows the sensed data obtained from a single node to be shared by multiple application requests. Previous research work in this field is challenged with an increase in WSNs workload. The energy of sink nodes drains out quickly within a limited duration due to an increase in the number of sensing request tasks on the network. However, the Task-Alloc framework introduces two algorithms namely Hot-Tasking and Merge-OPT, to resolve the challenges mentioned above. The Hot-Tasking algorithm enables selecting desired sensor nodes for the retrieval of sensed data while other sensor nodes are set in sleep mode to conserve their energy usage. Suppose there are multiple similar requests from a single sensor node. In that case, the Merge-OPT (Based on Greedy Algorithm) algorithm is executed to merge them to become a single request for optimal sensed data retrieval from the desired node. Performance evaluation shows that both algorithms have the potential to conserve more than 76% energy usage of the WSNs when a new application request is added. An efficient Particle Swarm Optimization combined with Simulated Annealing (PSOSAA) algorithm is proposed in [50] for medical monitoring and managing cloud-based IoT infrastructure applications. The proposed algorithm is implemented in a middleware residing on the cloud resource database. The particle swarm optimization algorithm searches for the actual sensor node among multiple seamless sensor nodes that can deliver the required data as requested by end-users, considering the proximity between potential sensor nodes. On the other hand, the simulated annealing algorithm is implemented to support the particle swarm optimization by increasing its searching ability in order to obtain the best sensor node required for the acquisition of sensed data in real-time for the continuous monitoring of patient health. In [51], a collaborative scheduling algorithm for a mobile sensor-enabled cloud system is implemented to minimize the number of activated mobile sensing devices. Sensed data from a specific mobile device is used to satisfy the request of multiple applications. The research work is based on a middleware that mediates between multiples of applications requesting sensed data and mobile sensing devices. The energy consumption of mobile sensor devices is minimized with the No-Aggregation algorithm implemented in the middleware. Also, the Info-Aggregation algorithm determines the tradeoff between energy efficiency and the amount of sensed data to be offloaded by active mobile sensing devices onto the IaaS cloud. The middleware regularly decides which mobile sensing device to activate from the multiple networked mobile sensor devices on a real-time basis. Hence, the desired sensed data are transmitted to the Cloud for further processing and storage. Table IV denotes the various types of algorithms that utilize the meta-heuristic and hybrid process in this research.

A closed-loop design model based on the Genetic algorithm for Cloud assisted IoT middleware is proposed in [52], to monitor the condition of multi-manufacturing engineering systems. System design weaknesses, failure, and predicting system health status are monitored on a real-time basis to proffer a timely solution to improve the system redesign process and performance status. WSN nodes are embedded in the manufacturing system components situated in different locations for operational data gathering (precision, temperature, and production speed) to determine their condition in real-time. The operational sensed data are transmitted via Bluetooth communication network from the multiple WSNs to gateways. Consequently, the sensed data are preprocessed in the gateways before they are offloaded to the cloud. The cloud is responsible for storing all the sensed data received from multiple WSNs, evaluate and translates them into knowledge base information (e.g., components weaknesses and failure, production speed and precision). Hence, to effect timely improvement, minimize

TABLE IV. COMPARISON OF META-HEURISTIC/HYBRID PROCESS

S/N	Algorithms				
	Article Title	**Algorithm Name**	**Challenges**	**Achievement**	**Future Improvement**
1	A Task Execution Framework for Cloud-Assisted Sensor networks [49]	i) Hot-Tasking Algorithm ii) Merge-OPT based greedy algorithm iii) Merge-OPT based Hybrid algorithm	Increase workload of sensor nodes	Merging of same multiple sensing requests satisfied by a single sensor node resulting in energy conservation	To investigate and formulate a security mechanism to prevent potential threats in the future.
2	The monitoring and managing application of cloud computing based on Internet of Things [50]	i) Efficient particle swarm optimization algorithm ii) Simulated Annealing algorithm	Searching for a suitable sensor among multiple seamless sensors considering their proximity	Improves searching capability thus obtained actual sensor required to fulfill the on-demand desired request.	To resolve the strict mathematical proof of convergence issues with an efficient algorithm, while giving priority to sensory task to be scheduled before they are dispatched for sensing event.
3	Energy-aware collaborative sensing for multiple applications in mobile cloud computing", Sustainable Computing [51]	i) No-aggregation algorithm ii) Info-aggregation algorithm	The Trade-off between energy efficiency and sensed data offloading	multiple requests satisfied by a single mobile sensing device while others remained in-active resulting in energy conservation	Future work is to address the provisioning of applications with various options for partial covering and reliable covering of requested regions by mobile devices.
4	Closed-loop design evolution of engineering system using condition monitoring through the internet of things and cloud computing [52]	i) Genetic algorithm	Monitoring and provisioning of sensing data	Improves monitoring and efficient provisioning of timely sensed data	To Investigate the systematic approach in WSN-Cloud for the extraction of related features of sensing for detecting potential manufacturing design weaknesses.

S/N	Algorithms				
	Article Title	**Algorithm Name**	**Challenges**	**Achievement**	**Future Improvement**
5	A collaborative resource management for big IoT data processing in Cloud [53]	i) Non-dominating sorting-2 ii) Pareto strength evolutionary-2 model	Selection of suitable sensor resource providers with efficient sensor networks energy consumption	Optimized selection of desired sensor resource providers for execution of task requests and prolonging the lifetime of sensor network nodes	To deploy Bee and Ant colony algorithms or a combination of both to enhance the partner selection problem in the future.
6	DEED: Dynamic Energy-Efficient Data offloading for IoT applications under unstable channel conditions [54]	Dynamic Energy Efficient Data offloading Scheduling algorithm	Unstable transmission channel conditions of offloading sensed data from IoT sensing device(s) to the fog and cloud for storage.	Enhances the reliability of transmitting sensed data via the desired communication channels to the cloud while conserving energy usage.	To study the issue of fault tolerance model for the offloading of sensed data in order to further improve the data reliability and investigate the channel quality-awareness with respect to Zigbee protocol for the development of distributed scheduling techniques.
7	Workload-aware VM consolidation method in edge/cloud computing for IoT applications [55]	Workload-Aware Virtual Machine Consolidation (WAVMCM) algorithm	The inability for edge devices to process tasks in a power saving mode.	Minimizing the number of active server utilization leading to energy conservation.	To determine how to minimize the use of hazardous materials, heat generation and cloud computing resource wastage.
8	Multimedia Sensing as a Service (MSaaS): Exploring Resources Saving Potentials of at Cloud-Edge IoT and Fogs [32]	Truncation-Point-Optimized Resource Allocation (TPORA) algorithm	The issue of bandwidth scarcity during sensed data offloading to the cloud	Effective allocation of optimal bandwidth rate for the offloading of sensed data into the cloud storage server.	Not Specified

Table IV. This table illustrates the comparison of previous algorithms that adopted meta-heuristic and hybrid process for resolving issues of the WSNs resources in Cloud-IoT, thus showing their results and future improvement about the performance of the algorithm.

production cost and increase productivity. In [53], a global collaborative cloud data center for resource management provision is proposed to process numerous and heterogeneous IoT's data set. The research aims to determine suitable means for targeting cloud providers or data centers across the globe that will form a cloud confederation. It utilizes multi- genetic algorithms namely Non-dominated Sorting-2 and Pareto Strength, to optimize selection among various cloud providers with the desired WSNs. The genetic algorithms optimize the selection by utilizing the profit gain and trust relationship information of individual cloud providers that intend to join the cloud confederation. Also, a trust model for the cloud provider selection that uses both objective and subjective trust values is adopted to confirm the trustworthiness of the collaborating cloud providers, ensuring the validation of cloud providers involved in the collaboration. Truncation-Point-Optimized Resource Allocation (TPORA) algorithm is developed in [32], to allocate communication resource (bandwidth rate) to the sensed data, based on their level of quality, without considering the unstable channelization conditions. Optimal bandwidth rate is allocated to premium packets sensed data compared to regular sensed data to be offloaded in the cloud. However, [54] develop a Dynamic Energy Efficient Data offloading Scheduling algorithm. It resolves unstable channelization communication during offloading sensed data from IoT constrained devices to the cloud. Duplicate sensed data records retrieved from the sensor nodes are backed up to ensure reliability. After that, the earliest and expected time are computed to determine the possible time a device (e.g., mobile phones) in the network can offload its sensed data to the cloud. The device with the least computed time among other devices can offload its data on the cloud before others. Therefore, the constrained devices' energy usage is drastically reduced by selecting the device whose energy exceeds the threshold value to transmit sensed data. In contrast, others are put on sleep mode. Consequently, [55] implemented a workload-aware Virtual Machine (VM) consolidation algorithm to switch the idle physical server into hibernation mode. The resources of the physical machine are classified into four classes with diverse resource capacities to execute different VM requests. At the initial stage, new VM request tasks are aggregated depending on their resource demand. After which, they are allocated to a VM class that is capable of storing the sensed data. Therefore, VMs from low load servers are migrated to intermediate load servers within the same class and determine the physical servers inactive mode, thereby hibernating them to minimize power consumption.

6. EFFICIENT QOS DELIVERY PARAMETERS

The WSNs constrained issues, such as the inefficient transmission of sensory data resource (s) to the IaaS-enabled cloud data center that leads to the energy consumption of WSNs, has been resolved significantly by the existing algorithms. The algorithms' effectiveness and efficiency were evaluated and validated based on metric parameters of Quality of Service (QoS) delivery in the Cloud-IoT platform. These parameters include Sensor Quality, Energy, Accuracy, and Throughput, Cost efficiency, Priority, Latency, Bandwidth rate and Data loss recovery [56]. Sensor quality is measured by the level of its sensitivity and accuracy of covering a specific region within a given time [57]. Energy Consumption is computed with regards to a particular energy model. For instance, the determination of the total volume of data transmitted. Therefore, energy usage directly influences the lifetime of any sensor network. Throughput is sensor nodes' ability to transmit their sensory data over a link to their connected sink nodes within a given period [58]. Accuracy is the level of performance obtained during sensed data mining or analytics (management). Cost efficiency determines the sensor-cloud capacity to efficiently allocate limited resources to execute sensing request tasks that leads to optimized resource utilization. Data recovery refers to accessing logically or physically damage data without any functioning backup [59]. Priority is the means of given precedence to a specific task for execution before others. In WSNs, precedence is given to suitable sensory nodes that can deliver the desired sensing data requests. Latency determines the timeframe delay in the sensory network during the sensing task process. The bandwidth of physical sensor nodes is the measurement of bit-rate available for communication between sensor nodes to sink nodes and to the cloud IaaS platform. Table V depict the authors and their respective algorithmic processes used to actualize the efficient quality of service delivery (QoS) parameters. In table V, column three illustrate the Cloud-IoT hardware components which comprise of cloud data storage/virtual machines, and physical sensors, deployed by researchers for the actualization of resource management in Cloud-IoT infrastructure. Furthermore, different gateways are also used to manage data transmission by reducing the communication distance between the WSNs and cloud data center while improving the communication speed. The measurement of sensor quality is classified into two types, namely lightweight and heavyweight. The lightweight sensors are mostly deployed for capturing data signals, while the heavyweight is used for capturing multimedia data signals such as images and live video streaming from a camera fitted sensor nodes to the cloud IaaS platform. The level of efficient QoS delivery actualized by the existing algorithms as presented in Fig. 4. The chart shows that sensor node quality has the greatest consideration than other parameters. It also shows that clustering and meta-heuristic algorithms have the highest implementation of QoS parameters based on the level of each parameter. However, throughput is mostly considered for the validation of meta-heuristic algorithms. On the other hand, energy happens to have the highest level of usage by the queuing algorithms. Furthermore, throughput and data recovery are least considered for the performance validation of clustering, classification and queuing algorithms. Accuracy is highly used to validate the performances of clustering and classification algorithm without its consideration in meta-heuristic algorithms. The cost efficiency determines the minimum amount of resources (such as the bandwidth rate, number of sink nodes and other gateways) use in transmitting sensing requests from the cloud data center to various WSNs. Also, the retransmission of sensed data requests from the WSNs back to the cloud. Furthermore, the computation tasks such as data gathering and the aggregation of multiple sensed data are efficiently performed in the cloud platform. The minimum time required for sensing coverage was also actualized, which is termed as latency for selecting the desired sensor nodes for sensed data delivery. In a nutshell, QoS contributed immensely for the actualization of efficient sensed data delivery.

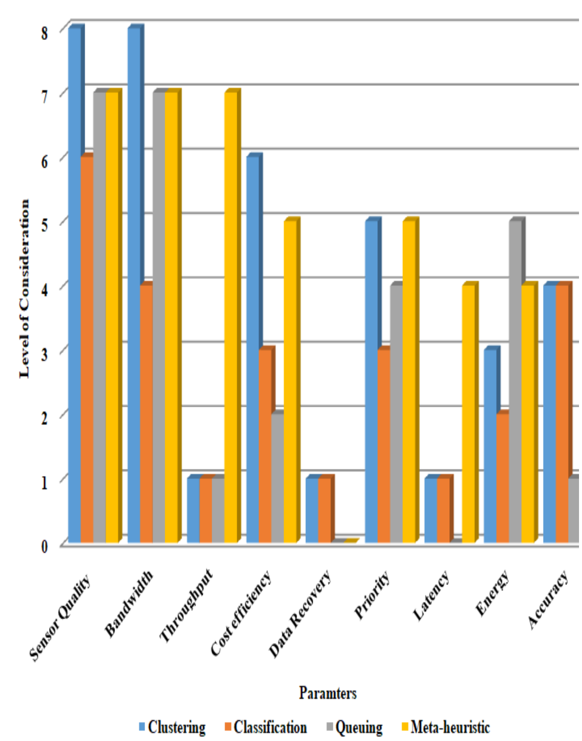

Figure 4. QoS performance of the Existing Algorithms

TABLE V. EFFICIENT QUALITY OF SERVICE (QoS) DELIVERY PARAMETERS IN WSN-CLOUD-IOT

S/N	**Comparison of Parameters**														
				Gateways			**Parameters of QoS**								
	Algorithms	**Reference**	**Cloud-IoT Component (VMs, WSNs, Servers)**	**Smart Device**	**Sink Node**	**Cloud Broker**	**Sensor Quality**	**Band width Rate**	**Energy**	**Through put**	**Cost Eff.**	**Loss Data Recovery**	**Priory**	**Latency**	**Accuracy**
A	**Clustering Process**	Mitten et al.[24]	Yes		Yes	Yes	Light weight	Less			Yes				
		Mehmood et al. [25]	—	Yes			Heavy weight				—	Yes	Yes		
		Liu et al. [26]	—			Yes	Heavy weight				Yes		Yes		Yes
		Ismail and Hassan [27]	—		Yes		Light weight		Yes				Yes		Yes
		Ismail et al. [28]	—			Yes	Heavy weight								Yes
		Renna et al.[29]	—			Yes	Light weight		Yes				—		
		Redondi et al. [30]	—	Yes			Heavy weight		—	Yes				Yes	Yes
		Abawajy et al.[31]	—	Yes		Yes	Light weight				Yes		Yes		
B	**Classification Process**	Wang et al. [33]	—	Yes			Heavy weight	—			—				Yes
		Madhavaiah et al. [8]	—		Yes		Light weight		Yes				Yes		Yes
		Bijabooneh et al.[34]	Yes		Yes	Yes	Light weight	Less							
		Faria et al. [35]	—			Yes	Heavy weight								Yes
		Ko et al. [36]	—		Yes		Light weight	—	Yes				Yes		Yes

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S/N	**Comparison of Parameters**														
				Gateways			**Parameters of QoS**								
	Algorithms	**Reference**	**Cloud-IoT Component (VMs,WSNs, Servers)**	**Smart Device**	**Sink Node**	**Cloud Broker**	**Sensor Quality**	**Band width Rate**	**Energy**	**Thro. put**	**Cost Eff.**	**Loss Data Recovery**	**Priory**	**Latency**	**Accuracy**
		Sun et al.[38]	Yes			Yes	Heavy weight	Less			Yes				
		Lyu et al. [39]	—			Yes	Heavy weight	—	Yes	Yes			Yes		
		Bonifaci [40]	—			Yes	Light weight	—							
		Hou et al.[41]	—			Yes	Light weight	—	Yes						
C	**Queuing Process**	Jutila [42]	—		Yes		Light weight	—							Yes
		Kumar et al.[43]	—			Yes	Light weight	—			Yes				
		Zhu et al. [44]	—			Yes	Light weight	—	Yes				Yes		
		Chen et al. [45]	Yes		Yes		Light weight	—	Yes				Yes		
		Liu et al. [46]	—			Yes	Heavy weight	—	—	Yes				Yes	
		Shiet al. [49]	—	Yes			Light weight	—	Yes	Yes			Yes		
D	**Meta-heuristic Process**	Lou and Ren [50]	Yes		Yes	Yes	Light weight	Yes		Yes			Yes	Less	
		Loomba et al.[51]	—	Yes			Light weight	—	Yes					Less	
		Xia et al. [52]	—		Yes		Heavy weight	Yes		Yes	Yes		Yes		
		Alelaiwi [53]	—			Yes	Light weight	—			Yes				
		Yan et al. [54]	—	Yes			Heavy weight	—	—	Yes				Less	

S/N	**Comparison of Parameters**														
				Gateways			**Parameters of QoS**								
	Algorithms	**Reference**	**Cloud-IoT Component (VMs,WSNs, Servers)**	**Smart Device**	**Sink Node**	**Cloud Broker**	**Sensor Quality**	**Band width Rate**	**Energy**	**Through put**	**Cost Eff.**	**Loss Data Recovery**	**Priory**	**Latency**	**Accuracy**
	Meta-heuristic Process	Mohiuddi and Almogren [55]	—	Yes		Yes	Heavy weight	Less	Yes		Yes	Yes	Yes		
		Wang et al.[32]	—				Light weight	—		Yes	Yes		Yes		

Table V. It shows the parameters used to evaluate and validate the algorithms in order to determine their feasibility and performance. Also, it indicates that the existing algorithms mainly resolve the energy issue of the WSNs by using the computation power and storage features of the cloud to execute and store the huge amount of sensed data retrieved from the WSNs.

International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. 10, No.1 (Feb-2021)

7. DISCUSSION AND CONCLUSION

It is estimated that the Internet will be composed of multi-billion connected devices, leveraging their storage and computation processes with cloud platforms' support across the globe. These connected devices include Radio Frequency Identification (RFID), wired and Wireless Sensor Network (WSN) nodes, actuators and mobile sensing devices. Network communication channels from IoT devices to sink nodes and gateways and the cloud data center are gaining developmental stride daily. For instance, the LTE and 5G network communication technology were recently introduced to improve the communication overheads between IoTs connected devices and the Cloud IaaS platform. Though, the existing algorithms were able to resolve some of the challenges of managing WNS physical features and the data they generate to reasonable extents. However, they are not designed to handle the dynamicity and heterogeneity of big sensed data on a real-time basis, which is highly required in IoT. WSNs are known to generate a massive volume of data that conventional machine learning algorithms cannot manage. However, the combination of clustering techniques has been proven to be useful for handling big data in previous research, but it still requires further improvements regarding time computation complexity issues. For instance, delay in execution time and high cost of computation that leads to high usage of memory and storage resource(s). Resolving this problem will enhance clustering techniques to obtain better extraction of meaningful and desired data from the sample dataset. In the aspect of WSN, the existing algorithms mainly tend to reduce their energy usage with or without emphasis on how they can be deployed in a hostile environment for optimal and reliable sensing or event capturing. This can be handled with more advanced mining algorithms such as recommender systems and neural networks, together with sensor devices capable of capturing, pre-processing, and transmitting data or events to a local server or directly to the cloud for onward processing. As opposed to WSN nodes that are constrained with low memory and storage resource(s) and not transmitting the data captured directly to sever or the cloud platform.

In conclusion, an overview of the existing algorithms was analyzed on how they managed WSNs physical features virtually and its sensed data generation in the Cloud-IoT infrastructure. Consequently, the algorithms' future enhancement for better performance, as stated by previous research, is highlighted, which paves the way for future research directions. Detailed background information is presented about the origin and present state-of-the-art IoT and Cloud, as well as the factor that resulted in their integration. Also presented in this paper is the actualization of notable QoS parameters to validate the performance of the algorithms for the delivery of sensory data, the conservation of energy usage in WSNs and optimal usage of memory/computation processes in the Cloud IaaS platform. However, there are other potential issues to be addressed for the optimal performance of the Cloud-IoT platform, considering security and privacy. In the future, a specific meta-heuristic algorithm that has not been used previously will be designed and implemented to manage IoT devices.

ACKNOWLEDGMENT

Special thanks to Dr. Alade Abel, for his support and contributions. The Authors will also use this medium to thank the Research Management Centre (RMC) Universiti Teknologi Malaysia for supporting this study, with research grant (QJ130000.2451.07G48).

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