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IOT based Big Data Analytics for Smart Buildings: A Survey

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Abstract: *The goal of the digital transformation procedures has been to increase productivity, safety, and execution quality, as well as to promote sustainable development, teamwork, and solutions for the sustainable smart city. The main digital developments are transforming the construction industry and exposing new trends for integrating information technologies. Systems for managing smart buildings today use a range of sensors, actuators, and dedicated networks. Their goals are to assess the state of particular places and implement the necessary regulations to maintain or enhance comfort while conserving energy. In this paper, we suggest a survey of IoT- and Big Data Analytics-related activities in smart buildings.*

Keywords: IoT

I. INTRODUCTION

Numerous studies have been conducted with the aim of implementing various types of applications such as energy optimization, simplification of building management, enhancement of residents' comfort, reactive alarm management, personal protection, asset protection, intrusion event management, etc. This is due to the growing interest in intelligent buildings and the emergence of new technologies in this field. This study emphasis is made more important by the rise in security flaws brought on by interactions between cyber and physical entities. The suggested intelligent management systems provide topological visualization for building security, the production of pertinent features, and the testing of access control rules to satisfy security obligations. Recent studies have suggested using standard information when simulating buildings. These procedures make advantage of relationships, subsystems, and sensor ontologies to guarantee portable and interoperable applications. At this time, the Internet of Things (IoT), which is made up of all the linked sensors, and the storage environment for the data produced by these sensors, are the two indispensable parts of smart buildings. IoT has emerged as the essential technological component of intelligent structures; any contemporary building intended to be intelligent must therefore incorporate linked items. It is crucial to comprehend how the Internet of Things (IoT) is integrated into this type of architecture in order to supply administrative tools that will make them as dynamic as feasible and enable the most joyful experience for its inhabitants. Furthermore, without analyzing the data produced by this vast network of connected things, it is difficult to make these buildings intelligent and dynamic. The initial step in analysis is to set up an adequate ecosystem, store, clean, and prepare the data, and then select the best analytical technique for each sort of facilitation required. But for intelligent buildings, storing and searching large amounts of data in real time is a difficult operation. The components of the technology ecosystem for smart buildings are depicted. With a focus on IoT and Big Data, the two major technological elements in our setting, the main goal of this work is to review the most recent literature on smart buildings.

II. IOT IN INTELLIGENT BUILDINGS

The improvement of cities and infrastructure, but most importantly the enhancement of resident comfort, depends heavily on smart building. It enables greater energy efficiency, regulates safety-related issues, and offers a better framework for comfort, quality of life, and services provided upon demand by residents and companies. There are a few definitions put forth, most of which are related to the idea of "smart grid" and emphasize the energy component. Electrical devices on the grid that learn habits and adapt to behaviors are referred to as intelligent building systems when they are integrated with intelligent management systems, huge data storage, and analytics to facilitate and

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improve energy management. As a result, the introduction of IoT and Big Data technologies as well as the use of data in analytics and autonomous learning have led to the intelligent management of equipment and services. In general, there are three tiers that make up an intelligent system in an intelligent building:

- The infrastructure level of the input data: this level represents all the data sources produced by the building's connected items, including energy usage, humidity levels, interior and outdoor temperatures, the number of alarms that have been activated and deactivated, etc.
- System infrastructure level: this level is the brain of the intelligent system since it enables data to be gathered, processed, combined, and stored in a NoSQL database. As a result, this permits the use of this data for reporting purposes, autonomous learning via artificial intelligence algorithms, or information extraction via data mining techniques.
- The level of services: This is a list of the services the system provides to building managers, residents, and energy suppliers, among others.

2.1 Technology and Architecture

The set of IoT-based technology elements that power intelligent buildings and enable control and data generation for user services are their beating heart. The intelligent building's HVAC system supplies sufficient heating, sufficient ventilation, and an improved air conditioning system

Fig.1. Eco system Components technology of Smart Building

A modern building architecture should consider implementing intelligent building as a new technology from planning to execution. Real-time measurements and contextual data can be delivered by integrating IoT in intelligent buildings. With the aid of linked items, activities such as lighting, parking, utilizing home appliances, and access authorization can be detected. Additionally, real-time GPS position (including all locations visited by users) is now feasible. Mobile applications will also assist in the collection of other personal information, such as weight, gender, and age.An advanced database server with a massive data management architecture can manage all acquired data and forecast trends. One of the trends in these enabling technologies is the growth of the Internet of Things (IoT), as dealing with a complicated network of interconnected functional entities in various building components is one of the problems of intelligent buildings. There is a lot of potential for the IoT to significantly advance the achievement of the intended goals. The literature offers a number of definitions of technology due to the diversity of IoT stakeholders and applications. IoT can be realized technologically by combining three key strategies: objects-oriented vision, internet-oriented vision, and semantic-oriented vision. All items will have identification, detection, networking, and processing capabilities thanks to the IoT architecture, which will enable them to communicate with one another, share information, and create cutting-edge services online. Interconnection would enable context-sensitive dynamic decision-making capabilities, intelligence autonomy, and a more thorough understanding of complex systems. By offering a comprehensive network that facilitates ubiquitous computing and awareness of the growing context among devices, these capabilities pave the path for realizing the goals of intelligent buildings, including integrated ambient intelligence. The implications of IoT are twofold:

- Even if they weren't originally built with these characteristics, the incorporation of sensing, storage, networking, processing, and computing capabilities into common objects and their implementation online.
- Networks that incorporate the aforementioned things. They would then be reachable through the network as a result. IoT's ambient intelligence enables each thing to comprehend its surroundings, build meaningful relationships with people, and support their decision-making. It is envisaged that the technology will be useful to a range of industries, including health, manufacturing, retail, agriculture, industrial automation, etc., even if researchers still confront technological challenges in creating, deploying, and finally maturing IoT.

IoT has just started to become more prevalent in the construction sector as a trend. Through the effective use of IoT, researchers and practitioners are investigating its advantages and drawbacks. For instance, a number of businesses, such as IBM and Intel, are currently introducing their intelligent building products all over the world, showcasing the IoT's competitive edge and potential future trend. To the authors' knowledge, however, despite surveys on IoT-based intelligent buildings, there isn't a thorough assessment and analysis of IoT applications in the broad spectrum of future building development. The three-layer design, which includes the perception layer, network layer, and application layer, is the most popular IoT architecture. The target is integrated with perception nodes and networks in the perception layer, which is in charge of detection and data gathering. The network layer, which is the most crucial layer of the design because it unites different devices and the communication infrastructure, is in charge of data transit. The top layer, known as the application layer, is where end users communicate. When data is transmitted, it receives it and delivers it to users for use in other services. A general architecture with designated layers is shown in Figure 2.

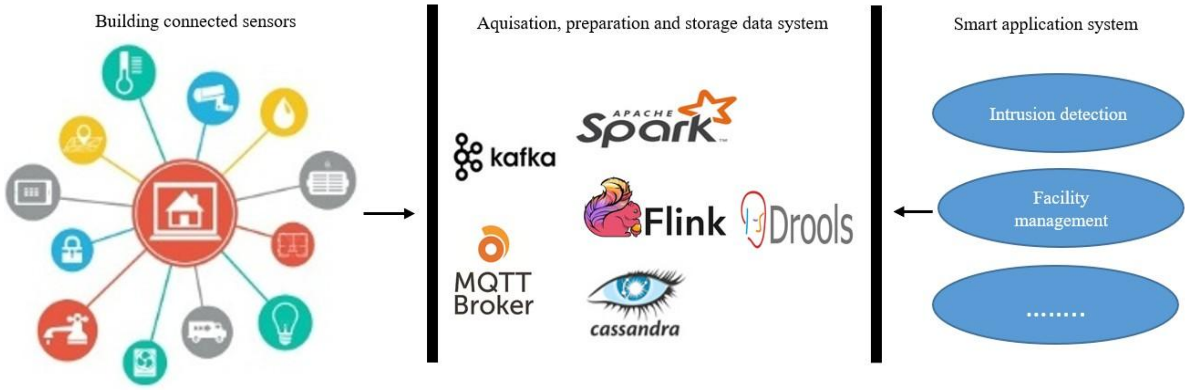

Fig.2. Generic architecture of smart buildings

2.2 Applications and Opportunities

Several applications, including the following, will result from the use of IoT in smart buildings:

- Facilities Management: The operating phase of a building's life cycle consumes the most time. Facilities management, which integrates organizational operations to ensure effective and efficient services, is thus another goal of intelligent buildings. To maintain the facility in the best possible shape, facilities management (FM) needs to perform timely preventative maintenance and identify any problems in building equipment. Lower data quality, longer notification periods, and delays in pertinent operation and maintenance are issues with traditional FM. Under these circumstances, IoT gives the concerned staff members adaptable and immediate access to the facilities of the building. IoT has just started to become more prevalent in the construction sector as a trend. Through the effective use of IoT, researchers and practitioners are investigating its advantages and drawbacks. For instance, a number of businesses, such as IBM and Intel, are currently introducing their intelligent building products all over the world, showcasing the IoT's competitive edge and potential future trend. To the authors' knowledge, however, despite surveys on IoT-based intelligent buildings, there isn't a thorough assessment and analysis of IoT applications in the broad spectrum of future building development. The three-layer design, which includes the perception layer, network layer, and application layer, is the most popular IoT architecture. The target is integrated with perception nodes and networks in the perception layer, which is in charge of detection and data gathering. The network layer, which is the most crucial layer of the design because it unites different devices and the communication infrastructure, is in charge of data transit. The top layer, known as the application layer, is where end users communicate. When data is transmitted, it receives it and delivers it to users for use in other services. A general architecture with designated layers is shown in Figure 2.
- Enhancement of interior comfort: Along with energy efficiency, occupant comfort is a key priority for intelligent buildings because maintaining comfortable living conditions for occupants is a basic necessity of structures. Additionally, since people spend 80% of their lives indoors, a comfortable and healthy interior

environment is crucial for occupant health and productivity. Real-time, robust monitoring and management of the interior built environment is required. Future HVAC systems will incorporate sensors and actuators at an advanced level, allowing temperature settings to be automatically modified in accordance with occupant preferences and needs based on past data obtained through empirical learning. An IoT system is used to develop these cognitive capabilities, including data gathering, decision-making, order sending, etc. The smart home is typically the first type of structure where studies on occupant comfort using an IoT system are conducted. In order to monitor the conditions of the indoor environment and the consumption of utilities in residential buildings, Kelly et al. designed an IoT system. IoT applications for occupant safety and health security, efficient resource management for convenience, and other topics have been researched in the literature.

III. BIGDATA AND SMART BUILDINGS

A significant amount of data is generated every second in the context of intelligent buildings and reaches critical sizes. Numerous large-scale data processing solutions have been proposed for this purpose. Spark and Hadoop are the industry standard options. Although Spark and Hadoop both use big data frames, their purposes are quite different.

If the operational and reporting requirements are largely static and it is possible to wait until the batch processing is finished, MapReduce's operating mode might be sufficient. However, we will probably need to use Spark if we need to analyse data in streaming, as is the case for processing sensor data in an intelligent building, or if applications call for a series of actions. This is true for the majority of machine learning algorithms, which call for multiple steps. Spark fits this situation just right. The process of analyzing various forms of data to derive models and knowledge using various data mining tools is known as knowledge extraction from data. Numerous applications, including those in the analysis of health care data, the educational system, production control, and decision-making, among others, use data mining. There are numerous clustering algorithms, including the expectation maximizing grouping algorithm, self-organizing cards, hierarchical grouping algorithm, and K-means algorithm. The size of the data set, the number of clusters, the type of data collection, etc. are all factors that influence which algorithm should be used. The worldwide goal of intelligent buildings can be realized through the analysis of this vast amount of data in order to streamline building management, save energy consumption, secure people and property, and offer a more convenient living environment. We briefly describe a few popular methods used to investigate data generated by and saved from smart buildings in this section:

- Probabilistic graphical model: A specific structure of conditional algorithms is used in this algorithm division's probabilistic graphical model to study the relationships between the variables for which sensor data has been collected. In most cases, it is divided into two stages. The first phase involves understanding the structure of variable dependency, which is a crucial step in Bayesian networks. Learning the conditional probability distributions for the connected variables in the graph makes up the second half. This is a crucial component of practically all graphical models that are routinely used to determine the likelihood of a space occupied.
- System identification techniques: The goal of the graphical model was to record data on the typical occupancy of a building's various spaces as well as the relationships between those spaces' occupancies. To improve construction, Stoppel et al. have included probabilistic techniques into building energy simulation models. For modelling regular occupancy in commercial buildings in single-occupation and multi-occupancy multi-zone areas, respectively, Chen et al. suggest non-homogeneous Markov chain models. Lam et al. used hidden Markov models (HMM) to accomplish the following goals, including occupancy detection with 80% accuracy. The HMM approach is an effective prediction technique because it directly predicts the time correlations between environmental variables and subsequent time step occupancy levels. System identification methods: System identification methods build mathematical models of dynamic system models using statistical methodologies. Using the following statistical methods, many algorithms of this type in the field of building occupancy estimate try to find building occupancy profiles. Given a specific set of the building's geometric and physical features, disturbances and the number of occupants are on one side, and other monitored variables are on the other. The best dynamic identification methods that connect the two sides are found through technical identification systems. A method was used to create a building's occupancy model. However, the authors determine the number of occupants during the inference using the estimated model and outgoing

observation Offices, break rooms, corridors, conference rooms, and restrooms are just a few of the sites within a structure for which Duarte et al. discuss occupancy diversity variables. The ultimate goal was to disseminate knowledge to aid facility management, energy optimization, and assistance with enhancing security in the event of an entry.

- Vector support machines: Support vector machines (SVMs) are within the category of supervised learning algorithms. Their goal is to predict a building's condition with regard to facility management, resident comfort, and security by estimating the occupancy rate or zone. The SVM algorithms try to identify the largest margin hyperplane that may divide the data into occupied and empty state categories. Non-linear kernel functions, such as radial basic functions, can be used to describe pair data to larger dimensions and be used effectively for classification. Shih use SVM to monitor and count people both throughout the day and at night. Based on the likelihood (similarity) between the specified target model and the characteristic vector acquired in the test instance, the authors used the SVM to estimate the observation density. In their research on the contextual detection of office occupancy using data from smart metres, Akbar et al. use three different types of VCMs: those with RBF cores, those with linear cores, and those with polynomial cores.
- Data mining and clustering: Unsupervised learning techniques to extract important data on trends in a building are well documented. utilizing a clustering strategy, Chen et al. investigate non-intrusive occupancy monitoring (NIOM) utilizing thresholding over three metrics: mean power, standard deviation, and power range obtained from energy metre data. Doca et al. provide a mining paradigm that focuses mostly on rule induction. Data mining is used by Zhao et al. to understand how building inhabitants behave. To extract locations of high use areas, Nguyen et al. employ a categorical non-parametric clustering method for unsupervised learning.
- Numerous techniques and algorithms have generally been applied to smart buildings to date. These consist of data mining algorithms, statistical and traditional learning techniques, neural network-based techniques, and probabilistic graphical modelling. The goal and calibre of the data determine how well these strategies perform and how they are evaluated.

IV. CONCLUSION

The research that has been done to date on the creation of smart buildings is presented in this article as the state of the art. We started out by talking about the Internet of Things, which opens up new possibilities for smart building management. The vast amount of data gathered by sensor networks is fed into Big Data databases, opening up the opportunity for in-depth analysis to pinpoint the demands of smart building operators based on models. In our upcoming study, we suggest integrating sensor data with an ecosystem of intelligent services to govern people's movement dynamically in smart building spaces. We intend to use a case study in our upcoming work

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