VOLUME 18, N° 2 2024
Journal of Automation, Mobile Robotics and Intelligent Systems

A Numerical Analysis Based Internet of Things (IoT) and Big Data Analytics to Minimize Energy Consumption in Smart Buildings

Submitted: 3rd April 2023; accepted: 16th September 2023

Amal Zouhri, Abderahamane EZ-ZAHOUT, Said Chakouk, Mostafa EL MALLAHI

DOI: 10.14313/JAMRIS/2-2024/12

Abstract:
The new wave of performant technology devices generates massive amounts of data. These devices are used in cities, homes, buildings, companies, and more. One of the reasons for digitalizing their tasks is that over the past few years, there has been an interest in reducing carbon emissions and increasing energy efficiency to create a friendly ecosystem and protect nature. One of which granted the explosion of data. After deploying these new devices, a significant increase in the use of the other face of energy to implement the components of the new devices was noticed. Above all, the interconnection of these intelligent devices is the central concept of the Internet of Things (IoT). This domain has widened the possibilities for the interconnection of building management systems (also named Smart Grids) and devices for better energy management. Furthermore, its potential is realized only after organizing and analyzing a large amount of data. Real-time management and maintenance of big data are critical to improving energy management in buildings. The benefits of big data analytics go beyond savings on electricity bills. It can provide comfort for building users and extend the life of building equipment, enhancing the value of commercial buildings. Intelligent interconnection of a building's technical installations (lighting, heating, hot water, photovoltaic installations, etc.) not only allows for connected management of this equipment but also meets high energy efficiency criteria that indicate an increase in comfort and energy savings. With building automation, the technical installations of a building interact optimally. In this article, we will simulate an intelligent building based on the Cisco packet tracer software. To better manage the energy consumption of our project, we will focus on the processing of data in real-time, especially since we will have a massive amount of data generated by the sensors, which makes the use of big data mandatory.

Keywords: *virtual smart grid, modern electricity networks, intelligently manage, generation consumption, stability, electricity supply and demand, packet tracer*

1. Introduction

In the past, a building needed only four walls, a roof, and sometimes a floor to function. Building projects have become much more complex as more sophisticated technologies have been created, including wireless networks, networked computers, electricity, and telephones. Modern structures are equipped with sophisticated systems that provide comfort and information, making them almost like living organisms [1].

The advent of the Internet of Things (IoT) and big data has brought about a significant transformation in the field of smart buildings. Smart buildings are designed to be more energy-efficient, sustainable, and responsive to the needs of their occupants [2–5]. By integrating IoT technologies and harnessing big data [6], these buildings can optimize energy consumption, improve occupant comfort, and enhance overall operational efficiency [7, 8]. One key aspect of a smart building is the collection and analysis of vast amounts of data generated by various sensors and devices installed within the infrastructure. These sensors continuously monitor different parameters, such as temperature, humidity, occupancy, lighting, and energy usage, among others [9–13]. The data collected is then processed and analyzed using sophisticated algorithms and artificial intelligence techniques to gain valuable insights into building performance and occupant behavior [14].

Energy consumption is a major concern in modern society, and smart buildings aim to tackle this challenge by employing IoT-based sensor networks for real-time data collection. The data collected from these sensors allows building managers to optimize heating, ventilation, and air conditioning (HVAC) systems, lighting, and other energy-consuming components, leading to reduced energy wastage and cost savings [15–17]. Moreover, the integration of smart building technologies enables better prediction and control of energy demand, which is particularly crucial in today's energy-constrained world. Advanced energy storage solutions, such as smart phase change material (PCM) walls, can help store excess energy and release it during peak demand periods, making buildings more energy-independent and resilient [18]. Additionally, smart buildings promote occupant well-being by monitoring indoor environmental quality (IEQ) factors, such as air quality, temperature, and humidity [15–19].

IoT-based air quality sensors can detect common insulation problems and ensure healthy indoor environments by timely detecting and addressing issues related to ventilation and air circulation. The combination of IoT and big data technologies has opened up new possibilities for enhancing energy consumption in smart buildings. Through the integration of intelligent systems, data-driven decision-making, and optimized resource utilization, smart buildings are revolutionizing the way we construct, manage, and inhabit our built environments, leading us toward a more sustainable and energy-efficient future.

The increasing interest in intelligent buildings and the emergence of new technologies in this area has resulted in a number of studies that aimed at implementing different types of applications. These include energy optimization, simplifying building management, improving resident comfort, reactive alarm management, personal protection, asset protection, intrusion management, and so on. Recent research has suggested describing buildings with consistent metadata modeling. These practices are based on sensory ontologies, subsystems, and relationships, ensuring interoperability and portability of applications. At present, we cannot talk about smart buildings without mentioning two inseparable components, namely the Internet of Things (IoT), which is made of all the connected sensors, and the storage environment for the data generated by these sensors. It has become the key technological element in smart buildings. Any modern construction designed to be smart needs to incorporate connected objects. In addition, it is impossible to make such buildings smart and dynamic without analyzing the data generated by this mass of connected objects. One of the most recent advances in this field is the intelligent building, which is a highly energy-efficient architecture capable of controlling the storage, distribution, and supply of energy. It aims to achieve rational consumption by using the technologies of connected objects (IoT) and mass data processing. This notion calls for a concept called "Smart Grids," which are currently used in electricity distribution networks to manage energy in the best possible way. This involves taking into account all the actions of stakeholders (consumers, users, and producers) in order to modify the production and distribution of energy according to fluctuations in demand, particularly consumption peaks. This method reduces waste and improves energy supply. The inhabitants of a building can be assured of a balanced production and distribution of energy by applying this idea to that specific structure. The main purpose of this work is to examine existing documentation on smart buildings, focusing on IoT and big data, which are the two major technology components in our context. This paper is structured as follows: it introduces the concept of intelligent buildings and related technologies. Then, it focuses on the field of the Internet of Things, its architecture, and its applications. An operation test follows this section and examines analytical approaches applied based on a big data ecosystem, and after that, a conclusion for this paper is the final step. The rest of the paper consists of the related work in Section 2; Section 3 provides an overview of Smart Grids; Section 4 discusses big data predictive analytics for Smart Grid stability; the results and discussion in Section 5, and finally, Section 6 for conclusion and perspective.

2. Related Work

Concerning the analysis of buildings to understand energy use, the initial solutions were mainly aimed at using nondeterministic models based on simulations. A variety of simulation tools are available with different capacities. Park et al. estimated that research into the application of big data to smart city construction involves building a technical framework for the development of smart cities from the point of view of exploring, managing, analyzing, and applying data paths. Talaris et al. have analyzed and found that while search angles are varied, these searches are based on web API information integration, metadata, semantic aggregation, and knowledge graphics technology remaining at the conceptual level, and how to make good use of big data technology needs further clarification. Simon et al. discuss that if a larger system is required to extract data from the energy efficiency management platform at a later stage, this is often not feasible. Even where possible, it is necessary to customize the development of interfaces and corresponding transmission protocols, which is long and expensive. At present, the development and construction of smart buildings at home and abroad are in the development and exploration stage. Jiang et al. believe that the energy efficiency of buildings is the use of intelligent technologies for measuring the energy consumption of buildings and analyzing the energy efficiency of equipment, adoption of systems integration methods in order to build platforms for measuring and managing energy consumption, and by a global management of the energy efficiency of buildings in the supply of hot water, lighting, appliances and other aspects in order to obtain better energy saving effects. Chrysi et al. (2020) present practical approaches to enhance energy efficiency and environmental sustainability through the adoption of smart building technologies and IoT-based energy management strategies; this is achieved by a nonlinear model linking power demand to the required temperature profile. A genetic algorithm based on such a model is then used to optimize energy allocation, match the user thermal constraints, and allow the mixed-integer deterministic optimization algorithm to determine the remaining energy management actions. Consequently, a more integral vision is needed to provide accurate models of energy used in buildings [21–32].

3. Theoretical Study

3.1. Smart Grids

A "Smart Grid" refers to an electrical energy distribution system that autonomously adjusts to production and demand. The Smart Grid integrates and modifies production and consumption models to achieve optimal safety and energy efficiency. This is facilitated by a network of sensors, real-time data transmission, analysis tools, big data, and other advanced techniques.

3.2. Characteristics of Smart Grids

Smart Grids can be defined by four key characteristics: flexibility, reliability, accessibility, and economy.

Flexibility: Smart Grids enable precise management of the balance between energy production and consumption.

Reliability: Smart Grids enhance the efficiency and security of the entire energy distribution network.

Accessibility: Smart Grids facilitate seamless integration of renewable energy sources into the system.

Economy: Smart Grids lead to energy and cost savings due to improved management of energy production and consumption.

3.3. Internet of Things (IoT)

The IoT refers to a distributed network connecting physical objects capable of communicating with each other, other devices, or computers. These objects can detect or act upon their environment. The data transmitted by these devices can be collected and analyzed to reveal insights and suggest actions that save money, increase productivity, or improve the quality of goods and services.

3.4. Connected Objects

In the context of the Internet of Things, a "connected object" denotes any electronic device capable of communication and information exchange via a PC, tablet, or any other device equipped with wireless or Bluetooth connectivity.

3.5. Characteristics of Connected Objects

Connected objects possess the following distinctive attributes:

Identification: Each object has a unique identification code, such as a barcode, IP address, or RFID tag.

Environmental Awareness: These objects are equipped with detection, analysis, treatment, and alerting capabilities, making them sensitive to their surroundings. They can measure parameters like temperature, humidity, gas levels, and energy consumption.

Interactivity: The connection between an object and the network can be permanent or temporary, depending on the object's specific needs and function.

Virtual Representation: Each connected object has a unique signature and physical manifestation, represented virtually in the IoT system.

3.6. The Constituent Parts of IoT

Five essential components constitute the IoT system:

Sensor: Measures external parameters in the environment.

Embedded Software: Allows the connected object to store, retrieve, process, and evaluate data before transmission.

Transmission Chip: Facilitates data transmission after processing.

Customer Interface: Renders transmitted information understandable and useful to the user.

Battery: Provides power to the connected objects, enabling their functionality.

4. Home Automation and Its Objectives

4.1. Home Automation

It is the setting up of networks linking the different equipment of the house (such as the WiiFi system, the home automation, and the kitchen and bathroom appliances).

It includes a wide range of services, allowing the integration of contemporary technologies in the home.

As a result, we may distinguish between two areas of application home automation:

- Th management of energy flow (water, gas, and electricity), which includes the control of heating, lighting, ventilation, and household appliances
- The control of information flow coming from the computer, radio, and phone

4.2. Objectives of Home Automation

Home automation contributes significantly to the realization of a perfect life to the human being, with four main objectives (comfort, security, energy saving and health).

Comfort

- Open doors and windows without force using the cell phone.
- Turn on and off the light remotely.
- Air conditioning of the house (hot in winter and cold in summer).
- The refrigerator declares its need for food through a message on mobile.
- Create life scenarios and automate your home.

Security

- Protect the house against theft.
- Avoid accidents of burned gas, fire and electrocution.
- Centralize the house (all doors and windows close).
- Monitor the house remotely through cameras and alarms.
- The fixed telephone automatically call the fire department in case of emergency.

Energy Saving

- Control the lighting of the house.
- Set the machines for a certain period of time like washing machine.
- Turn off energy-consuming objects if you are not going to use them, for example, if you are sleeping and leave the TV on.
- Control the thermal exchanges with the outside. Optimization of domestic hot water production

Health

- Home automation helps the elderly and disabled to handle things in the houses.
- Sensors and measurements of the health of patients, such as blood pressure, body temperature, and blood sugar levels.
- Make the medical visit remotely through special equipment placed in the home.

5. Practical Study

We will present the simulation part performed by the Cisco Packet Tracer software

5.1. Packet Tracer

Packet Tracer is a Cisco software that allows the building of a virtual physical network. The user builds their network using equipment such as routers, switches, or computers, and recent versions of PT integrate IoT equipment (smart devices, sensors, actuators, microcontrollers, smart windows, smart fans, smart lights, alarm sirens, etc.). This equipment is linked via connections (various cables, optical fiber, etc.). Once all the equipment is connected, it is possible for each of them to configure the IP addresses and the available services.

5.2. Equipment Used for the Simulation

We used a variety of equipment in our simulation, including connected objects, programmable objects, test objects, and intermediate equipment.

1) Connected Objects: The following figure illustrates the different equipment used:

   Figure 1 represented the connected objects used in the simulation.

2) Programmable Objects and Test Objects: For the test we will use objects like fire, and for the movement, we use the movement of the mouse and programmable cards like the MCU.
3) Intermediate Equipment: The router, the switch, Home Getway, the modem, the cloud, the servers to control our system, and an antenna for the cellular network are some of the intermediate devices we used.

5.3. Configuration Outside the Building

1) Router Configuration: The two IoT and DNS servers, as well as the Cloud, the central office server and the Switch, are all connected to the router through its three Gigabit Ethernet ports. We will configure it on the CLI.
2) Configuration of the Servers: We have two servers to configure IoT server and DNS server, for both we will specify an IP address plus the address of Getway and DNS.
3) The 3G/4G Cellular Network: We have chosen a cellular network (3G/4G), which allows us to connect to the server via a Smartphone at great distances, in order to have the possibility to remotely control all the equipment connected to the IoT server.

5.4. Configuration Inside the House

1) Home Getway: Its role is to link all connected objects either wired or wireless and give them IP addresses. We have secured the system against hackers by WPA2-PSK authentication with a password, this type is the most effective and takes a long time for the hacker to access the network.
2) Connected Objects: We have connected the objects with the Home Get way in a wireless way where we have made a modification in the network card (change to WiFi type) and clicked on the Smart Device button so that they have the possibility of accessing the network. programming part: We are going to use the microcontroller "Boards MCU." This equipment is programmable to control and command a task in the desired way, where we have chosen the Script language in Figure 2.

Figure 1. Architecture IoT connected objects used in the simulation

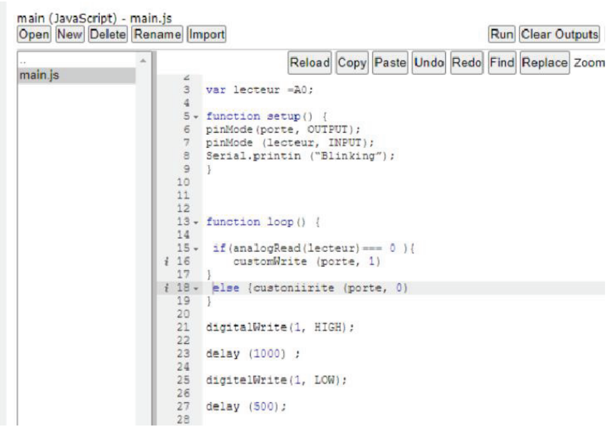

Figure 2. Programming the MCU board

The creation of the conditions requires that the objects work at the same time or one according to the other. There will be a master object and slave objects. When the master object turns on, the slave objects also turn on, and the same goes for turning off.

Intelligent building planning in Figure 3 simulates just one apartment in the building, and its prototype is composed of a bedroom, a living room, a kitchen, a bathroom, and a corridor.

We have placed our objects in the apartment in a homogeneous way in order to cover all the apartment, and we have placed the HomeAway so that it is convergent to all the objects and so that there will not be cuts of connection or a weakening of flow, then we will control some tasks, namely:

- The security system: by using the surveillance camera equipped with a motion detector and a siren. Thus, when the detector detects a movement, the webcam records everything that happens and the alarm sounds.

- The fire detection system: We also tested the fire detection system, and found that as soon as a fire is detected, the doors open, the alarm goes off, giving people time to escape the building.

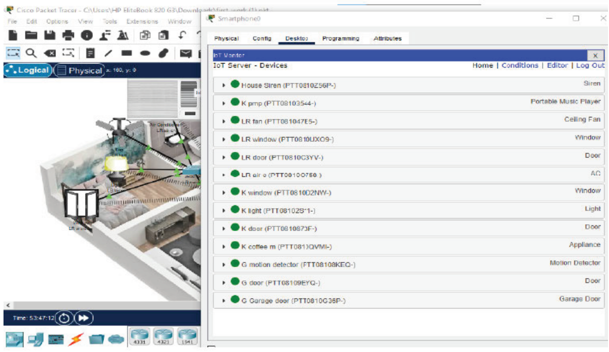

Figure 4. Server interface to control the objects

- The building temperature control system: In this system, we placed a thermostat that measures the temperature of the building after it turns on the air conditioner or the furnace according to the measured temperature.
- Control of doors and windows: One of the functions of an intelligent building is the remote control of doors and windows. As these are connected to the home network, we can open and close them using our smartphones.
- Lighting control: We can also control the light in the smart building either automatically with the motion sensors or with the smartphone using the IoT monitor application Figure 4, we can access the network and the IoT server through our smartphone, PC and tablet.

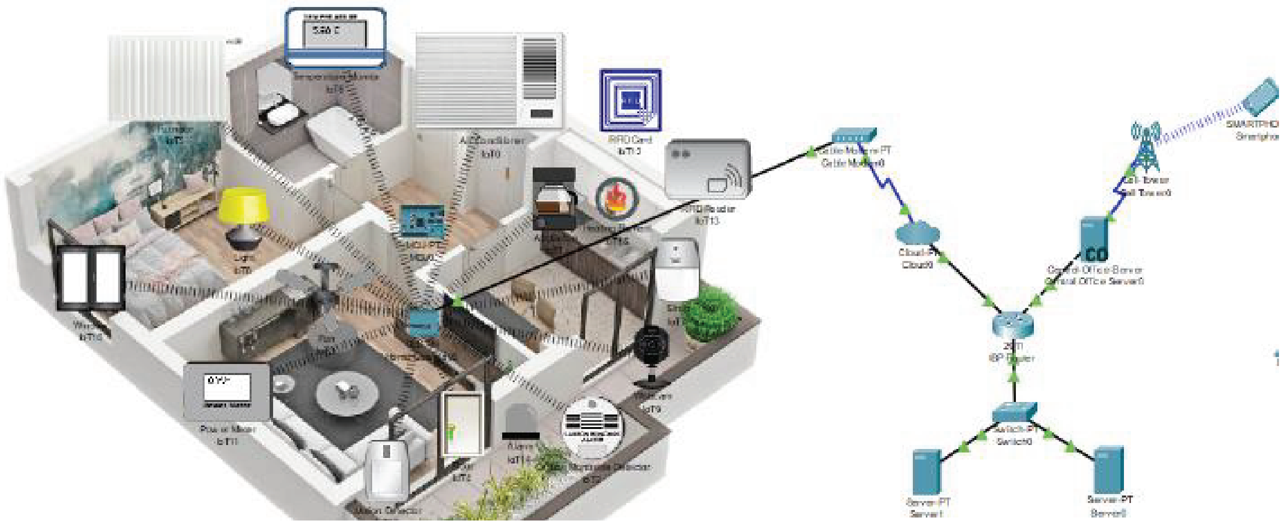

Figure 3. Intelligent building planning

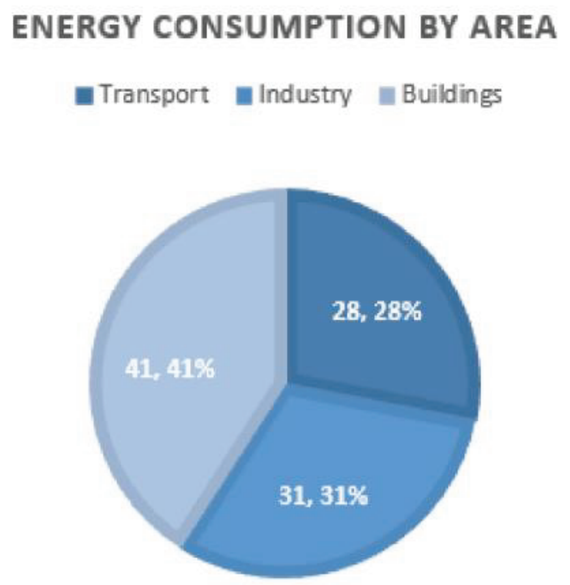

Figure 5. World energy consumption

6. Energy Efficiency in the Field of Intelligent Buildings

When the building's equipment is intelligently and effectively interconnected, we can easily manage and control the energy consumption through a remote control that enables the piloting of these connected devices through a cell phone. By doing so, we can instantly detect any unusual value that will be higher than the average consumption by energy class and identify more quickly the errors, flaws, and irregularities in the functioning.

When we talk about the reduction of energy consumption, we are necessarily talking about buildings since they offer a high potential for energy savings and represent more than 40% of the total energy consumption.

Daily life requires a lot of energy (Fig. 5), cooling in summer, lighting at night, hot water, etc. Our energy supply relies largely on fossil fuels, the combustion of which generates CO_2 emissions.

Buildings are responsible for the largest share of CO_2 emissions in developed cities and can be classified according to energy classes ranging from class A (0 to 50 kWh/m^2 per year (most efficient housing)) to class G (451 kWh/m^2 and more (very energy intensive)). We consider a low energy building (BBC) when the conventional consumption of primary energy of the building for heating, cooling, ventilation, hot water production, and lighting is less than or equal to 50% of the conventional consumption reference (50 kWh/m^2/year). Consumption is expressed in kWh of energy and brought back to the square meter of surface.

The main objective is to reduce the needs: "passive" energy efficiency, and to supervise and manage the technical equipment of the building: "active" energy efficiency.

This gives energy gains by acting on different human and material parameters, among the best practices to use is the use of efficient products, to reduce energy consumption, it is essential to choose equipment with the best possible energy efficiency, that is to say the best ratio between energy consumed and the service provided.

On the other hand, the integration of renewable energies, the use of these energies in an approach of energy improvement allows to obtain a part of the energy necessary to the building (electricity, heating, sanitary hot water) in a renewable way and thus to decrease or even eliminate the external energy contribution. Thus The metering/measurement of consumption: The energy management of a building consists first of all in counting/measuring the consumptions.

For the electrical and gas part, a classic installation includes a general meter which provides the global consumptions for their invoicing by the energy distributor. An optimized installation includes in addition to the general meter, permanent sub-meters. Their main role is to establish the distribution of energy consumption by item (heating, domestic hot water, ventilation...).

The counting or measurement of consumption allows the realization of the energy balance, the awareness by the user or manager of consumption and is used for the estimation of the energy saving potential. It also guarantees a follow-up in time of the energy performance.

- multiply the power of your appliances (in KW) by the time of use (in hours);
- then multiply it by the price per kilowatt-hour.

The result will allow you to know which appliances consume excessive amounts of energy.

7. Relationship of Big Data with Intelligent Buildings

Faced with the evolution of science, technologies are evolving at the same time, among them the IoT, which allows objects to be connected to the Internet. This sees the flow of immeasurable data generated through the objects connected, which makes it important to be able to link these innovations to big data.

The IoT and big data coexist to allow for significant technological advances, as the volume of data exchanged increases and the number of objects connected to the Internet multiplies.

The big data collected by the connected devices can be used in real-time operations, such as monitoring energy consumption and reacting according to the situation, either by changing, repairing, or making another proposal.

The system can be incorporated with functions to control the energy consumed by the devices according to the user's wishes. If the electricity consumption exceeds a threshold value set by the user, the application is notified.

Smart IoT devices can collect energy usage data from each unit and store it in a database based that can

Figure 6. General architecture of smart buildings

be analyzed and reported on for energy conservation and analysis.

Buildings cannot be made intelligent or dynamic without first examining the data produced by this vast network of interconnected things. The first step in the analysis process is setting up a proper ecosystem to store, clean, and prepare the data. However, for smart buildings, storing and retrieving vast amounts of data in real time is difficult.

In general, there are three tiers that make up an intelligent system in an intelligent building: At the input data infrastructure level, all the data sources produced by the linked building objects are represented, including energy usage, humidity levels, indoor and outdoor temperatures, etc. The system infrastructure level, which enables the gathering, processing, combining, and storage of data in a NoSQL database, serves as the brain of the intelligent system. As a result, it permits the use of this data for reporting purposes only, or for knowledge extraction by data mining algorithms or machine learning by artificial intelligence algorithms. The system's catalog of services that are available to building managers, inhabitants, energy suppliers, etc. is represented by the service level.

Three layers make up the IoT architecture:

The layer of perception is in charge of sensing and data gathering.

Data transit is handled by the network layer, which also enables the fusion of different devices and communication infrastructure.

The top layer where users interact is known as the application layer.

Several applications will result from the use of IoT in smart buildings, including: Access to building facilities that is flexible and real time; Energy management is the macro view of energy usage in relation to building energy efficiency; Location of resources and occupants increasing indoor comfort.

Figure 6 represents the choice of big data technology based on the enormous amount of data generated every second in this context of intelligent buildings and approached critical levels. For processing massive amounts of data, numerous solutions have been put forth. Although Spark and Hadoop, the two most popular products on the market, are both large scale data

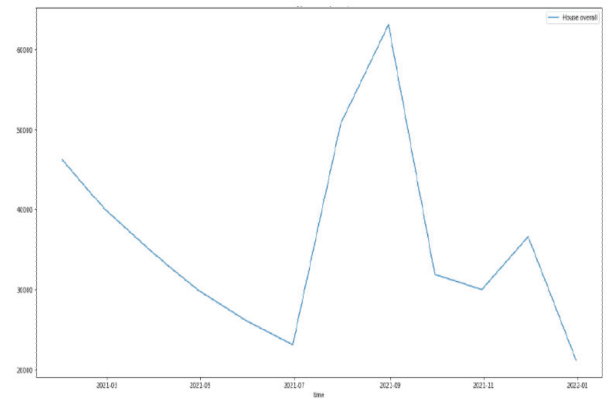

Figure 7. Overall energy consumption per month

frameworks, their applications are somewhat different. If the operating and reporting requirements are largely static and we can wait for the batch processing to finish, the MapReduce method of operation might be enough. On the other hand, we will probably need to use Spark if we need to analyze streaming data, such as analyzing sensor data in a smart building, or if the applications call for a series of actions.

Spark is the ideal solution in this situation. The process of examining various forms of data to draw patterns and information using various data mining techniques is known as knowledge extraction from data. The analysis of this massive amount of data contributes to the realization of the worldwide goal of smart buildings, which is to simplify building management, cut energy use, secure resources and people, and provide a more convenient living environment.

8. Application and Evaluation

In order to examine energy consumption, we utilized a dataset named "HomeC" which comprises of various objects and rooms that have been modeled after real-life counterparts.

Through our analysis of Figure 7, we discovered the energy consumption of each individual room and object. We observed that some rooms had higher consumption levels than others, and our goal was to reduce this consumption. To achieve this, we analyzed the objects present in these rooms to identify potential candidates for removal or replacement.

```
DatetimeIndex: 503910 entries, 2021-01-01 05:00:00 to 2021-12-17 03:29:00
Data columns (total 26 columns):
 #   Column               Non-Null Count   Dtype
---  ------               --------------   -----
 0   use                  503910 non-null  float64
 1   gen                  503910 non-null  float64
 2   House overall        503910 non-null  float64
 3   Dishwasher           503910 non-null  float64
 4   Home office          503910 non-null  float64
 5   Fridge               503910 non-null  float64
 6   Wine cellar          503910 non-null  float64
 7   Garage door          503910 non-null  float64
 8   Barn                 503910 non-null  float64
 9   Well                 503910 non-null  float64
 10  Microwave            503910 non-null  float64
 11  Living room          503910 non-null  float64
 12  Furnace              503910 non-null  float64
 13  Kitchen              503910 non-null  float64
 14  Solar                503910 non-null  float64
 15  temperature          503910 non-null  float64
 16  humidity             503910 non-null  float64
 17  visibility           503910 non-null  float64
 18  apparentTemperature  503910 non-null  float64
 19  pressure             503910 non-null  float64
 20  windSpeed            503910 non-null  float64
 21  cloudCover           503910 non-null  float64
 22  windBearing          503910 non-null  float64
 23  precipIntensity      503910 non-null  float64
 24  dewPoint             503910 non-null  float64
 25  precipProbability    503910 non-null  float64
dtypes: float64(26)
```

Figure 8. Information about the data

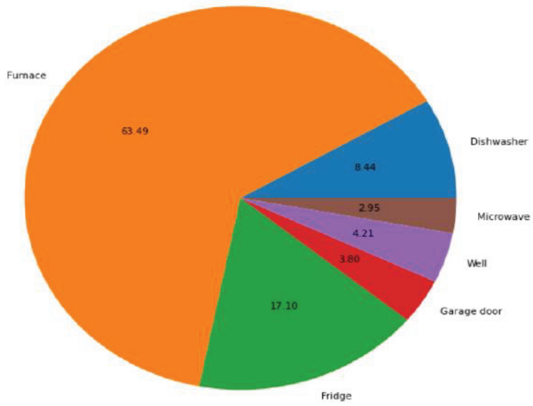

Figure 9. Consumption for devices

8.1. Dataset Description

Our dataset is thus in the form of a CSV file including weather data as well as household appliance measurements from a smart meter for 365 days in a period of 1 minute. The type of variables is important for data visualization:

used [kW]: Total energy used, gen [kW]: Total energy produced using solar or other energy sources, House overall [kW]: Represents the overall energy consumption of the building, for the other variables, it is the energy used by a particular appliance (dishwasher, oven, refrigerator, well, microwave).

8.2. Data Exploration

After reading the data from Spark, we will perform data preprocessing. This involves renaming the columns to remove spaces and the unit [kW], deleting the values, grouping some columns (such as the consumption of the kitchens we have in the building), and changing the format of the time in seconds to Y-m-d H-M-S. Thus, the information will be available from 2021-01-01 5:00:00 to 2021-12-17 03:29:00; Then, we will reorganize the columns. The data in Figure 8 represent the information about the data that will appear like this:

We can differentiate energy data and weather data to determine the month in which we will consume the most energy. We can see the total energy consumption for every month. To determine the month in which we will consume the most energy, we can see the total energy consumption for all the months.

A furnace consumes electricity to power the fan that circulates heated air throughout a building, as well as to ignite the gas or oil used to generate heat. Figure 9 represents consumption for devices. The electricity consumed by a furnace depends on several factors, including the size of the unit, the efficiency rating, and the length of time it is in use. In our data, the furnace consumes more than 63% of electrical energy.

We utilized the K-means technique, which divides the data into a predetermined number of clusters, to identify the classes. As a result, there are two classes of rooms energy: "Home office," "Wine cellar," "Kitchen," "Barn," and "Living room."

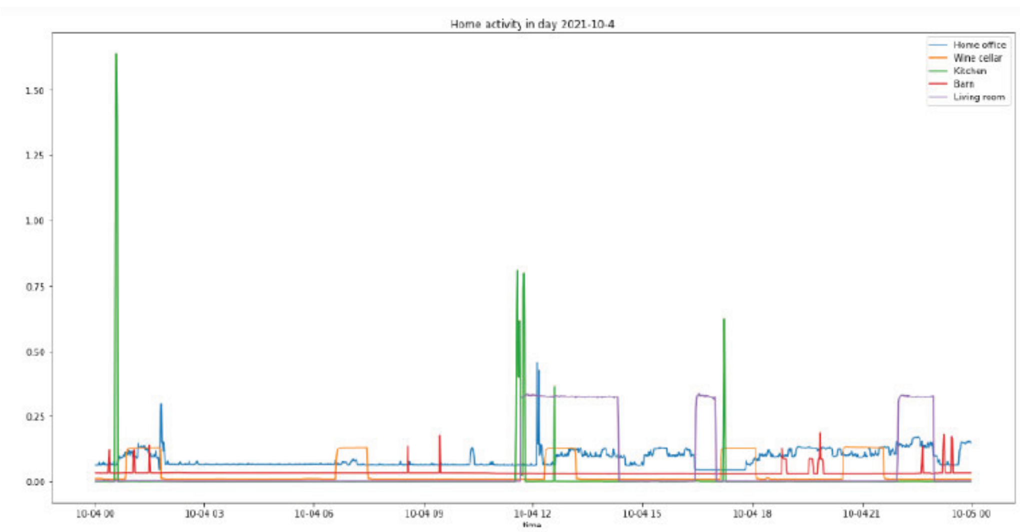

Figure 10. Home activity in day 2021-10-4

There is also a class of devices energy that comprises: "Dishwasher," "Furnace," "Fridge," "Garage Door," "Well," and "Microwave."

Let's consider the class of rooms in order to better understand how we can manage the energy consumption of the connected machines in the intelligent building. We will monitor the consumption of each member of the class so that if one of them exceeds the average of 0.22054800000000002 kW, we must decide to remove it. This is made possible by communication between devices. Here, we have analyzed the case of one day only, but we can generalize it later for all the days.

Figure 10 shows that the kitchen uses a significant amount more energy than average.

9. Conclusion

The modernization of cities has changed the ritual of energy consumption and new technology usage. This modernization, now called Smart Grid, hastened the evolution of interconnection between devices. This interconnection of smart devices (which are the source of data sensors like satellites and cameras and organization like the services granted to clients) requires important analysis capabilities. This is done with the help of big data tools to ensure real-time analysis and provide environmental context. This way, the consumer has the ability to remotely control their energy usage, and price rates can be updated if the level approaches a certain limit. As a result, they are allowed to make the choice of the effective time to use any device. This article has pointed out many features of home automation and added its objectives, followed by the utility of a virtual network software (i.e., packet tracer and its necessary equipment). Finally, this article expounded on the role of big data in the operation, management, and manipulation of the generated data.

AUTHORS

Amal Zouhri* – Sidi Mohammed Ben Abdellah University, Faculty of Sciences Dhar El Mahraz, LISAC Laboratory, Fez, Morocco, e-mail: amal.zouhri@usmba.ac.ma.

Abderahamane EZ-ZAHOUT – Faculty of Sciences – Mohammed V University Adjunct Professor at SSE "School of Science and Engineering" Al Akhawayn University – Ifrane Morocco, e-mail: a.ezzahout@um5r.ac.ma.

Said Chakouk – Researcher Professor at Faculty of Letters and Human Society, Mohammed V University in Rabat, e-mail: s.chakouk@um5r.ac.ma.

Mostafa EL MALLAHI – Sidi Mohammed ben Abdellah University, High Normal School, Fez, Morocco, e-mail: mostafa.elmallahi@usmba.ac.ma.

*Corresponding author

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