Fog Based Energy Efficient Process Framework for Smart Building

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ABSTRACT

The world is facing an energy crisis. The smart building concept is presented by many researchers using IoT devices that do not have sufficient computational power to compute the data to decide about the results. According to an estimation, there will be 50 billion IoT devices in 2020. Most IoT devices send data to the cloud for processing. Latency and network usage will be increased in cloud servers because the cloud servers will not be able to handle millions of requests spontaneously. In this paper, we have proposed a framework that minimizes latency and energy consumption in cloud computing. The proposed framework uses edge computing and most of the processing is performed on fog nodes. The framework contributes significantly to energy saving by supporting behavioral and physical changes in the cloud network.

CCS CONCEPTS

• **Software and its engineering**; • **Energy optimization process framework**; • **cloud and fog computing scenario for smart building**;

KEYWORDS

Internet of Things, fog with IoT, Energy consumption in fog computing, smart building, and fog node

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1 INTRODUCTION

Business organizations are focusing to make their workplace smart. Organizations are aware that they can grow their businesses and save energy by making the buildings smart. Every organization wants to save time and energy [1]. For this purpose, the organizations want to develop such a system that quickly controls the energy consumption and saves the energy and time of the organization. Every industry wants to save money and make its business processes efficient. Business organization consumes more energy than other organizations. In developed countries, most of the energy is consumed in business organizations such as banking, institute, and information system. In a banking organization or information system, there are a lot of devices connected with a server in cloud computing [2]. Each computer sends requests to the server and the server gives a response to the end-user. IoT devices send the data to cloud servers for processing. It is a time-consuming as well as an energy-consuming process.

Cloud computing is based on shared resources rather than local or edge to handle web applications and IoT devices. The latency rate of cloud computing is greater so it takes more time to process the data and consumes more energy of the organization. As a result of such conditions, more Co2 is produced. On the other hand, due to the huge amount of bandwidth usage, the organization pays more cost to internet service provider companies. To enhance the concept of cloud computing, Cisco launched Fog computing [3]. Fog computing is used to overcome the rapidity of the existing web application and save the consumption of energy and time. Cloud computing requires more resources like time and energy. If fog computing is used instead of cloud computing to control the IoT devices, then latency time and energy consumptions will reduce [4].

An organization uses thousands of devices in a network. These devices are connected through the internet and all of these devices send requests to the server and the server gives the response to each request which is a more complex and energy-consuming task for that organization [5]. If we use the fog node instead of cloud computing, the fog store data temporary and send the response to the user from the edge. For permanent storage of the data, the fog node sends the data to the cloud server. In the future, if the user needs this data, then it can be retrieved easily from the cloud server. Through fog computing, we minimize the response time and energy consumption which is more beneficial for business organizations [6]. Fog computing minimizes electricity usage daily which is a more important task for that organization. If we maintain the profile of electricity consumption daily of that organization, we will find out the reasons that consume more electricity. the organization is more focused on these reasons rather than other reasons [7].

Fog computing is an extension of cloud computing that processes the data at the edge [8]. This platform is becoming more popular for different kinds of applications such as IoT devices, mobile and web applications. Fog computing usage is most important for some applications or organizations over cloud computing. Some studies in the literature show that cloud computing requires more resources and energy to give a respond to the end-user quickly [9]. Fog computing is more energy efficient rather than cloud computing in

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an organization that has a lot of end-users connected through a centralized server [10].

In this paper, we aim to find out those networks in an organization that uses fog computing that is more efficient rather than cloud computing [11]. We also show that the same network uses cloud computing and Fog computing in an organization. We simulate both network devices and find out the latency of the network and give the results based on response time that which network is more energy-efficient [12]. The key features of the paper are:

- To minimize the latency over the cloud network.
- To make the network energy efficient.
- Minimize the response time over the cloud network regarding any query.
- To minimize the cost and time of the network resources.
- To minimize the production of Co2.

As the fog is not implemented at a vast platform so therefore simulations will run to evaluate the results. Different scenarios will be created in the fog simulator Ifogsim to evaluate the results. Graphs of latency and network usage will be created for each scenario in fog and cloud.

The rest of the paper is set out as follows. The related work is revealed in Section II. The proposed structure is defined in Section III. The findings are analyzed in Section IV. Threats to the Fairness of Section V The proposed framework's industrial implementation is shown in Section VI. Section VII brings the paper to a close, while Section VIII looks ahead.

2 RELATED WORK

Cloud computing is a centralized environment which gives resource distribution facilities to end-user or client [13]. Fog computing extends the cloud computing techniques in a way that reduce the response time over the cloud network. However, in fog computing, the resources are used in such a way that minimizes energy consumption over the cloud network. The literature reviews are given in table 1

3 PROPOSED FRAMEWORK

In this paper, we propose a framework that helps to reduce the energy consumption a network by using fog computing. Extending cloud architecture using over fog node significantly reduce the response time and latency of the network. In a cloud network, a central server is used and every component directly communicates to the server [19]. By using the client-server system, we need a lot of time to communicate with each device in a network. The proposed methodology is divided into subparts firstly, we will examine the results in cloud computing to determine the delay and response time. Then we consider the fog computing to find out the delay, response time and energy consumption. Many tools are presented for fog computing simulation. Finally, we propose a fog computing-based model to minimize energy consumption.

3.1 Cloud computing

Cloud computing requires scalable computing power and storage [20]. In cloud computing, the server can be accessed when we are connected with the internet. But in fog computing, the data source is available at each edge of the local host network. Cloud computing has high latency; due to high latency, the response time is greater, therefore, it is consuming more energy. We have calculated the latency and energy consumption in cloud computing through Ifogsim [21] using the algorithm given below.

Algorithm 1 Cloud Computing Algorithm

```
List of fog nodes ←(n)
List of sensors ←(n)
List of actuators ←(n)
number_user ← (n)
if cloud then
addModuleToDevice←("communication", cloud)
numOfApplincesConnected←Ø
for i=0 to less than Ø
Fog Device appliance= addAppliance();
end for
start simulation
stop simulation
createFogDevice
cloud=new createFogDevice( node name, maps, RAM, uplink
bandwidth, downlink bandwidth, hierarchy level of the device,
cost rate per MIPS used, busyPower, idle power )
for i=0 to numberofFogDevices
addFogNode
numOfApplincesConnected← v
for i=0 to v
AddAppliances
set gateway device ← fog node
end for
   end for
end
```

3.2 Fog Computing with IoT Devices

Fog computing can reduce the response time with IoT devices to minimize the energy consumption over the cloud network. Cloud computing cannot support video streaming and augmented reality [22]. There are a lot of differences in cloud computing and fog computing [6] which are given in table 2

3.3 Scenario A: Cloud Computing in Smart Building

In this paper, two scenarios are compared to smart buildings. Firstly, in one building we use the cloud server network, IoT devices send the query to the server through a network. The server sends the response to IoT according to their query. Their response time is significantly high when limited numbers of devices are connected. When the number of devices increases then the response time decreases, which is the biggest issue in large buildings that there are thousands of devices are connected. In this scenario, we have taken different appliances to connect those with the local server and the local server connection with a cloud server. When the user sends the data to the server it takes more time as compared to fog computing. We find out the latency with different appliances and energy consumption that their diagram is shown in Figure 1.

Table 1: Literature Review

Topic / Focus Questions	Achievement	Limitation	Reference
How to reduce the load on cloud computing? How to balance the load on cloud computing?	Authors used different algorithms for load balancing. In the study, fog computing is used instead of cloud computing and the cost of electricity is minimized.	The technique was applied only on building and limited resources. When applied to the large scale the methodology was failed. The authors did not compare the latency time of fog computing and cloud computing.	[10] [14]
How to reduce the cost of IoT devices without compromising the quality of service? To improve the lifestyle at home and office.	The study proposed the architecture and prototype for IoT devices using Audino IDE. The price of IoT devices is minimized.	The latency and effective communication protocol are not discussed.	[7]
How to automate the different aspects of smart cities such as transportation, energy system, water system, etc.?	They combine the fog and cloud network and create a middleware that fastens the communication.	Their methodology is not validated. It does not show accurate results in the run time environment.	[11]
What type of technique can be used to minimize the usage of electricity over the internet?	They proposed the architecture that supports different communication protocols.	The technique presented in the paper decreases the latency rate. It does not show the runtime results that how much delay time is minimized.	[4] [15]
How to minimize the usage of energy in the smart building using IoT devices?	They used the external devices micro servers to minimize the latency rate.	They minimize the energy at each phase but in the whole system, their approach fails in minimizing energy consumption.	[16]
Managing energy in buildings	The author proposes a framework that minimizes the usage of energy in buildings. They send the data of energy consumption to the user on a daily and weekly basis.	They focus on semantic web technology for a web application but they did not tell about the delay between communication devices.	[17]
Using fog computing over cloud computing can save energy.	They used the Nano server over the normal server to make the response fast.	They used the decentralize server for energy efficiency. Their approach fails on normal cloud and fog computing server.	[1]
Proposed a framework Does their framework reduce the cost of delivering data over the cloud network? How their framework allocates the distribution of resources.	They compare the different platform and find out the cost against each medium. Their framework allocates the proper distribution among different devices.	They did not tell about fault tolerance and privacy. They tell about the performance but not discussed how much performance is improved.	[18]

3.4 Scenario B: Fog Computing in Smart Building

In the second building, we have connected the appliances or IoT devices with different fog edges. The devices communicate with a server through edges. When the end user needs a specific data, the edge has stored the data and the user demands provide it from the edge. It minimizes the response time in a network that all the devices communicate with a server which is time-consuming and tedious for the user. Then we find out the latency and network usage and energy consumption. The Scenarios were compared cloud computing and fog computing and proposed a model that shows that fog computing using their edges are more energy efficient

Table 2: Comparison of cloud and fog computing

Item	Cloud computing	Fog computing
Latency	High	Low
Hardware	High scalability and computing power	Have limited storage at edge nodes
Server nodes location	At the internet	At edge nodes
Distance from client to server	Different server	One edge for each data
Environment	Within a building or within an organization	Used outside the organization like shopping mall street
Security	Distinct	Hard to describe

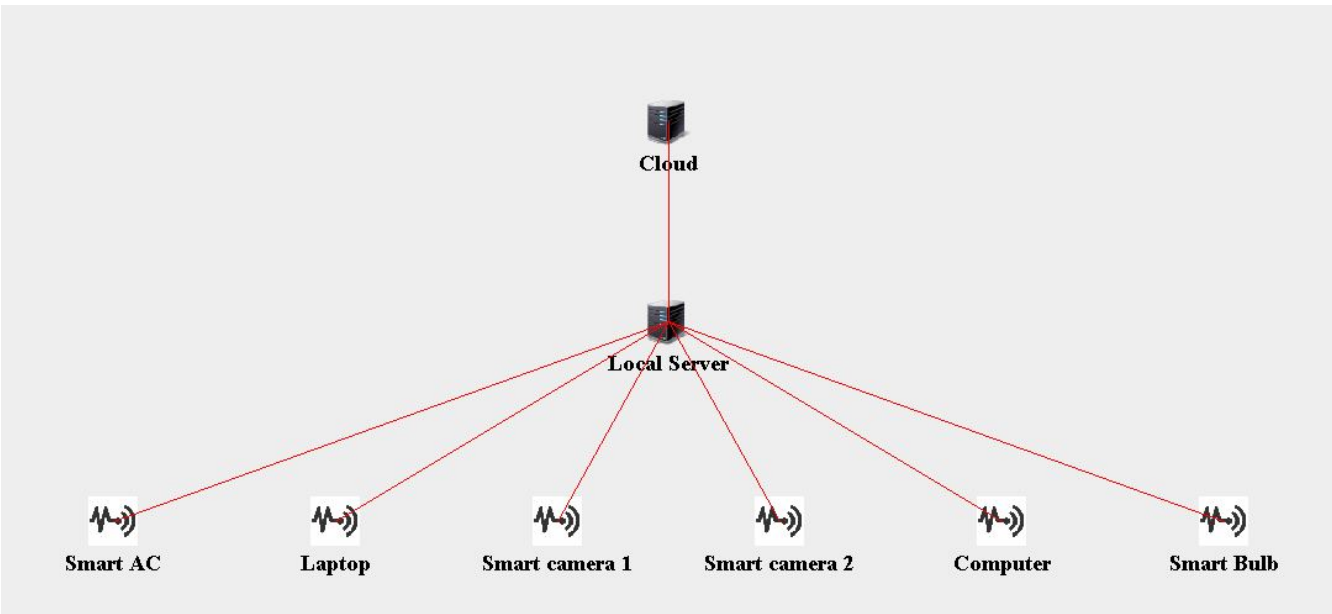

Figure 1: Cloud Computing in the Smart Building Scenario

using different devices in buildings. We divide the architecture into three layers. The first layer shows cloud computing, the second layer shows the fog computing and the third layer shows the dataset connectivity which is shown in Figure 2

4 EVALUATING RESULTS

In this paper we have a focus on smart building that using IoT device, to make a building more energy efficient. When IoT devices use a network and send the data properly to the server latency rate is high. We have performed an experiment using Ifogsim Tool on two different scenarios. In one building we have connected IoT devices such as camera, laptop, Ac, thermostat connected with the cloud server and these devices send the data to a cloud server through local server and give a response from the cloud server to each device. Then we find out their latency, network usage and energy consumption with different appliances which are shown in Figure 3

In the second scenario, we connected the different appliances such as a camera, computer, Ac, bulb using fog nodes. We find out the results using Ifogsim tool which we have calculated the latency, network usages, and energy consumption to connect the different appliance with fog nodes and find their correspondence results which are shown in Figure 4

5 THREATS TO VALIDITY

The key problems that may jeopardize the validity of the experiment's findings are implementation defects and errors. The implementation has been reviewed many times with different test set couples to minimize the effect of programming faults and errors.

Another significant threat is that the algorithm chosen for cloud and fog computing is ineffective. Some experimental parameters, such as latency and network use, may have an impact on the results we get from tracking behaviors with various tools.

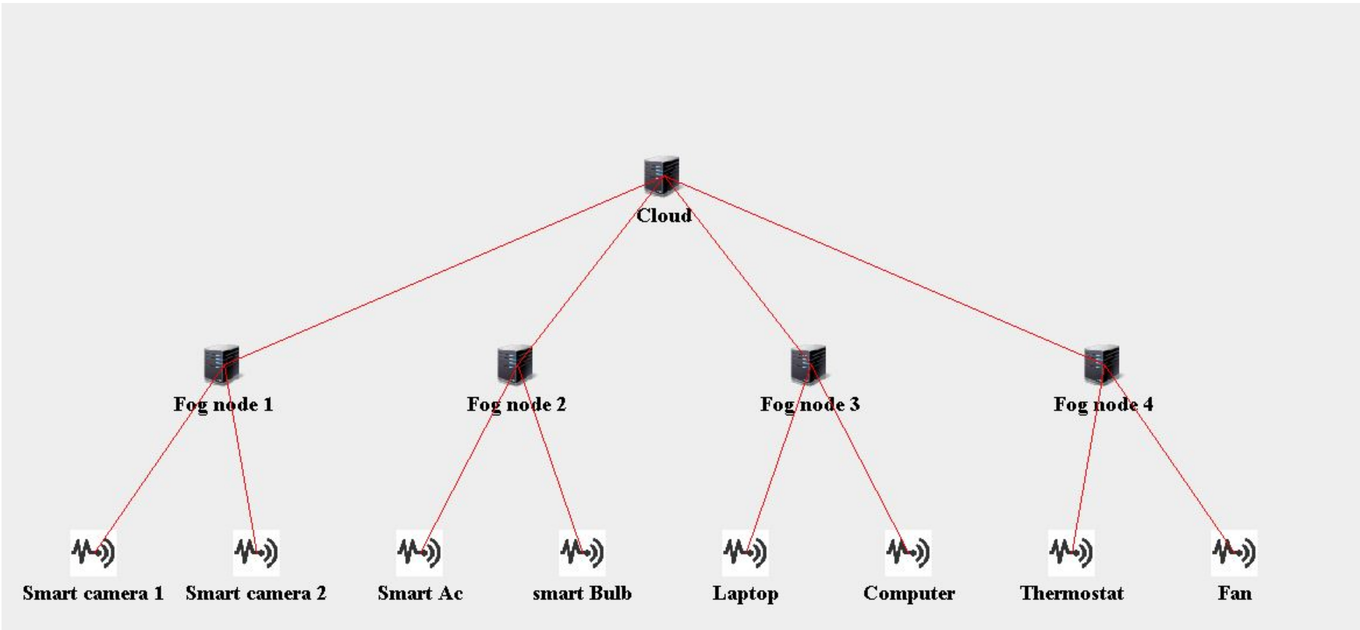

Figure 2: Fog Computing in Smart Building Scenario

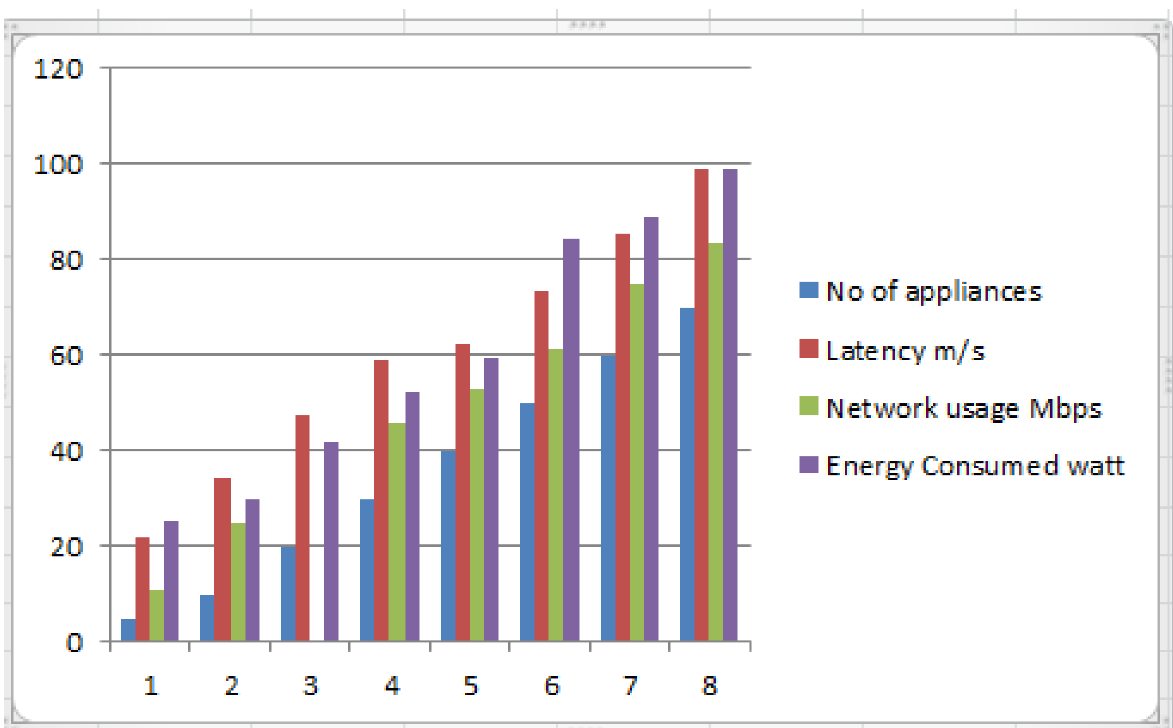

Figure 3: Cloud Computing Scenario Results

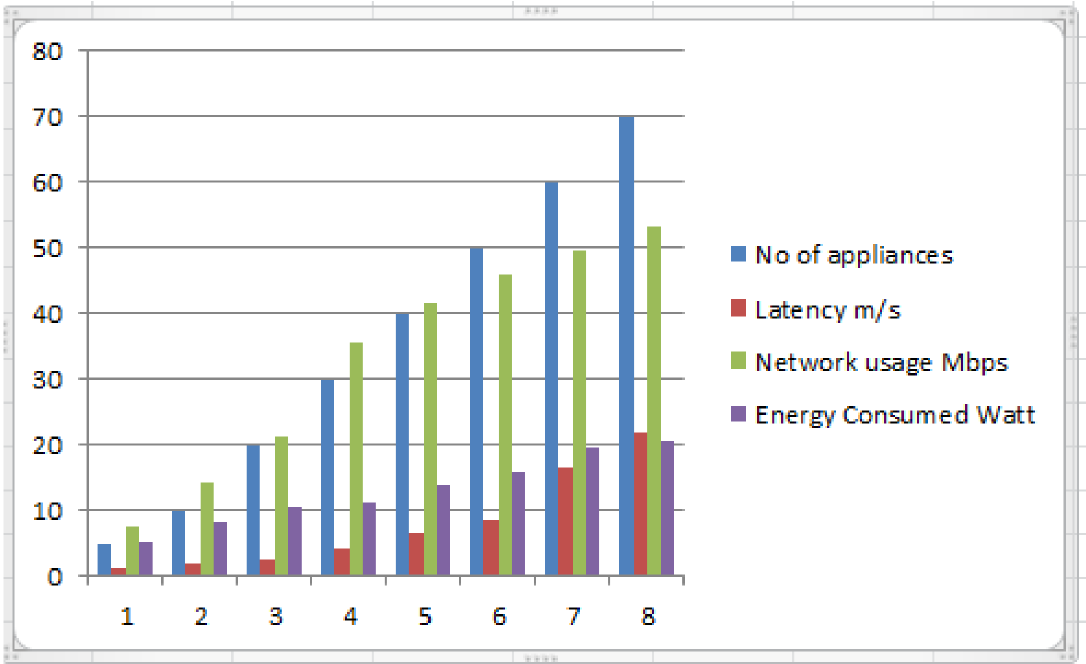

Figure 4: Fog Computing Scenario Results

Algorithm 2 Fog Computing Algorithm

```
List of fog nodes ←(n)
List of sensors ←(n)
List of actuators ←(n)
number_user ← (n)
if cloud then
addModuleToDevice ←(name, fogDevice)
numOfApplincesConnected←£
for i=0 to less than Ø
DeviceStartName←a
FogDevice appliance = addAppliance();
end for
startSimulation
stopSimulation
createFogDevice
cloud=new createFogDevice( node name, mips, RAM, uplink
bandwidth, downlink bandwidth, hierarchy level of the device,
cost rate per MIPS used, busyPower ,idlePower )
for i=0 to numberofFogDevices
addFogNode
numOfApplincesConnected← v
for i=0 to v
AddAppliances
set gateway device ← fog node
end for
end
```

6 RESEARCH AND INDUSTRIAL APPLICATION OF THE PROPOSED FRAMEWORK

During the last decade, the Internet of Things has piqued the interest of both researchers and practitioners. Certain operating systems and communication protocols are required to enable interactions between users and devices in the Internet of Things. Below is a high-level description of IoT in the application domain.

6.1 IoT technologies in smart cities:

Because of advances in information and communication technology, modern cities have become "smarter" and more effective in many ways. On the other hand, making every component in smart cities as a "smart" deployment of smart components is not needed, and it is even possible. To date, smart cities have used connectivity and network technology to solve contemporary urban challenges such as traffic congestion, pollution and the proposed framework can minimize energy usage in smart cities.

6.2 IoT technologies in transportation and mobility

The term "mobility" is sometimes used interchangeably with "transportation" in smart cities. Effective urban mobility, on the other hand, can be interpreted in a broader context. Intelligent transportation, also known as Intelligent Transport Systems (ITS), is mainly concerned with the deployment of Internet of Things (IoT) networks to solve transportation's various functionalities and applications.

6.3 IoT technologies in smart homes

One of the key goals of the proposed framework in a smart home is to efficiently regulate the devices and applications in a modern home, such as electronic devices, home indoor/outdoor security systems, climate control, light sensors, room temperature tracking, and appliance use, while reducing energy consumption.

6.4 IoT technologies in smart Retail and healthcare

IoT advancements in smart cities will promote online shopping and healthcare. Sensor data retrieved from smart devices carried or worn by people can be effectively used to allow remote retail and healthcare. In addition, the proposed system reduces energy consumption in healthcare and smart retail.

7 CONCLUSION

Internet of things (IoT) Devices contributes in a significant way to reduce energy consumption when we use fog computing in buildings. We conclude that by using fog computing in smart buildings we can save more energy as compared to when devices are connected through cloud computing. Using edge nodes in the smart building we have to minimize the response time of connected appliances. We have also minimized the cost of the resources that users in the network. Using the proposed technique, we can minimize the production of Co2 which makes our environment better.

In future, we will apply this technique on the smart city through which we minimize the response time for the user such as in banking, shopping centers, industries, that make the network more energy efficient and give quick response to the end user.

8 FUTURE DIRECTION

In order to simulate both the smart technology building template and the management system that controls energy usage in existing buildings, it is obvious that technical resources and equipment, as well as financial support, are needed. Our study was limited by these details. As a result, a beneficial and rational future aim of this research is to introduce and evaluate the data use and latency that tracks and controls the smart building template, as well as the implementation and testing of the management system that concludes the energy efficiency of an existing building and proposes solutions to transform it, according to the proposed framework.

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