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IoT-Enabled Smart Healthcare Infrastructure Maximises Energy Efficiency

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Abstract—Advancements in IoT-based applications have become the cutting-edge technology among researchers due to the wide availability of the Internet. In order to make the application more user-friendly, Android-based and Web-based technologies have become increasingly important in this cutting-edge technology. Smart cities, Internet of Things(IoT), Smart health care systems are the technology of the future. A combination of numerous systems focusing on monitoring different components of the smart city (such as water, e-health, gas, power monitoring and emergency scenario detection) can be used to make the city more sustainable and secure. In smart cities, energy consumption is particularly important for e-health. An optimization approach is provided in this paper to reduce total network energy usage. When compared to previous methods, the overall performance has improved by 57.89%.

Keywords- Energy, IoT sensors, e-health, optimization.

1. INTRODUCTION

In academia, industry, and government, smart cities are generating new ideas. When investments in human and social capital, and also traditional and modern communications networks, fuel long-term economic growth and a high standard of living, and natural resources are intelligently controlled through participatory government, a city can be considered "smart." A smart city is defined as a city that connects its physical infrastructure, social infrastructure, information technology infrastructure and commercial infrastructure in order to use the city's collective knowledge. Smart cities are typically built with superior infrastructure and modern communication and information technologies.

The Internet of Things (IoT), in particular, plays a crucial role in connecting together everything and to the Internet via specific protocols enabling exchange of information and communications, enabling for tracking, intelligent recognition, monitoring, location and management. IoT-based smart cities can provide a variety of services for residents and administration by connecting the physical and virtual worlds with massive amounts of electronic devices deployed in homes, automobiles, streets, buildings, and other public areas. Smart homes, weather systems, smart parking garages, vehicular traffic, surveillance systems, pollution, smart grids smart energy, are all issues that need to be addressed. As a result, more research into the technology and applications of IoT-based smart cities is required.

Global population growth is now progressing, resulting in increased resource demand. The globalization of the population, combined with the rural areas, has resulted in a buildup of environmental consequences in metropolitan regions. In 2050, it is estimated that there will be 6 billion people living in cities (70 percent of the world population). To address future problems, it would be required to make efficient resource allocations. As a result, cities have a significant amount of independence when it comes to resource management. Cities develop policies to limit resource waste in this situation.

The increase of citizens' quality of life is one of the goals of smart cities. As a result, daily issues such as traffic, energy waste, air and water pollution, and noise, to list a few, must be resolved or minimized. Finally, smart cities must manage natural resources produced in their proximity and consumed within the city to meet the needs of their population.

People put a high priority on their health. People anticipate that e-health services will become increasingly significant. The regulation of many significant factors can be utilized to save a patient's life. In both the home and the hospital, the use of health monitoring has proven to be helpful.

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When a parameter in these systems is outside of its normal range, the system produces an alarm. The emergency services, caregiver, or doctor receives the alarm and decides how to respond based on the severity. To lower the risk of death or disease complications, risk groups must be carefully monitored.

The Wireless Sensor Network (WSN) and Internet of Things (IoT) are extremely effective for resource management and city management [1]. Sensors allow us to keep track of the parameters we're able to research. As a result, we are able to make quicker decisions. Many smart city applications have been developed, including ones that monitor public parks, weather predictions, vehicular traffic, pollution, tracking systems, and e-health. Many efforts are currently ongoing to develop low-cost WSN and IoT solutions.

Compared to traditional sensor networks, these new sensor networks are less, despite their reduced accuracy. Because of the reduced costs and energy consumption, more sensors can be installed, assisting in the monitoring of city-related indicators.

2. RELATED WORK

The adoption of IoT in the healthcare industry will improve to monitor how patients are treated remotely, boosting healthcare personnel' efficiency. In [1] summarizes current research in the field of IoT and health care, with an emphasis on hardware needs, complexity, and obstacles.

A secure surveillance technique was proposed in [2] for healthcare system which uses IoT sensors that are enabled by video summary and encryption of key frame pictures. This work was divided into two parts. Firstly, the visual sensor triggers a well-organized key frame extraction process to extract significant image frames such as detecting abnormal/normal activities key frame with an alarm delivered to the appropriate authority in the healthcare system. Second, a probabilistic, encryption approach was proposed to maintain security from adversaries.

In [3] an interference reduction channel access mechanism (IR-CAM) was proposed as a new strategy for mitigating the effect of interference. To limit the effect of interference, the coordinator will adjust the contention frame length and window size. Both static and movable nodes are used in the simulations. Compared to transmission model, IEEE 802.15.4e, the proposed method uses 53 percent less energy on average. Performance analysis for numerous WBSNs is also included in the simulation.

The smart healthcare systems (SHS) development has been aided by advancements in wireless technology. SHS uses sensors, wearable's, and devices to monitor a patient's condition. To analyze the data, these parameters were forwarded to healthcare professionals or emergency services. During the transmission of the data privacy and security were considered.

First, a new classification methodology for SHS techniques that classifies them according to their domains of use was presented [4]. Second, developed a classification strategy for the SHS literature. And finally commonly occurring security threats in SHS were considered and also provided solutions. Finally, the open-research challenges of SHS security, privacy were discussed and offer solutions.

Federated Learning (FL) is proposed in this paper [5] as a technique to give distributed IoT users with privacy-preserving collaborative model training at the network edge. Users in the FL network, on the other hand, may have various degrees of willingness to participate (WTP), which is information that the model owner is unaware of. The results shows that the proposed design meets the limitations of IIC and generates more profits than the uniform pricing scheme, showing it is effective in optimizing effect of information asymmetry.

Many attempts are being made to strengthen the healthcare system, and sophisticated technologies such as cloud and IoT are being used. As a result, this paper [6] provides a detailed overview of the various IoT health models that are currently accessible. The research focuses on a variety of deployment methods for developing a cloud, IoT-based system to deal with a variety of health challenges. The article describes the massive benefits that the Internet of Things provides, as well as the most important concerns that must be overcome in order to fully automate the healthcare system. An integration of machine learning models to process healthcare data was discussed in the work.

An IoT-enabled system was proposed in [7] which were made up of a number of biosensors. These biosensors were attached to the patients. Before forwarding the data to database the sensors read, record data. A cloud server is in charge of processing, evaluating, and making decisions about the data that has been stored.

A comprehensive analysis of computer vision-based approaches for WCE video analysis was presented in this paper[8]. Firstly, WCE video analytics , their generic flow were identified. Second, a comprehensive evaluation of WCE video analysis tools and surveys, including their current merits and shortcomings were discussed.

The main focus of the work is discover research trends in different WCE disciplines and future research toward better healthcare system.

A detailed evaluation of machine learning algorithms for the healthcare sector was presented in [9]. Furthermore, the strengths and weaknesses of existing methodologies are discussed, as well as potential research

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difficulties. The work can help healthcare practitioners and government organizations stay up to date on the newest trends in machine learning-based big data analytics for smart healthcare.

[10] For smart healthcare data sharing systems, an SDN-based security enforcement framework was developed. In data sharing system there is a virtual machine for each patient which provides a set of data services to authorized service consumers or IoT devices. Furthermore, an SDN-based gateway protects the virtual machine by acting as a firewall.

A complete assessment of existing techniques was presented in [11], which includes most recent trends, cutting-edge techniques in the field. Firstly, techniques were presented which combine fine grained data semantics, multimodal association mining in a smart healthcare system. Second, approaches for cross-border association , multimodal data fusion in the development of smart healthcare systems was presented.

The building of a smart city using IoT devices was presented by Gaur et al. [14] and Anita Chaudhari et.al[15]. There were four levels to the architecture. In the first level, the sensors were collecting data. At the second level, semantic web technologies are used to process the data. At level three, data integration and reasoning are generated. New rules can be generated as a result of this. Finally, alarms are produced using the analyzed data in stage three. Vehicle, home, environment domain monitoring, and health as well as knowledge extraction, were recommended by the authors.

An optimization based neural network model was proposed in [12], to lower energy consumed in the mobile cloud network by varying parameters like loudness, variance. A number of low-power nodes are overlaid on top of the standard cellular system. However, as the number of femto cells grows, the network suffers from intra-tier and inter-tier interference, as well as delays. This study proposes [13] a sub-modular optimization based offloading approach to solve the bottleneck.

3. PROPOSED SYSTEM

The system that will make up future smart cities is described in this section. Various networks that are responsible for monitoring and controlling significant issues were integrated. Many application areas, including water resource monitoring, e-health, smart meters and smart gardening, among others are described.

E-health systems serve two major functions. On a one hand, the devices can be used to focus on the old, disabled, or persons with medical issues. In this situation, the system is designed to collect data in order to improve medical monitoring and life quality by allowing individuals more autonomy. The systems, on the other hand, are accessible to the average individual. In this case, the system is attempting to detect unusual activity and, if required, alerting emergency services.

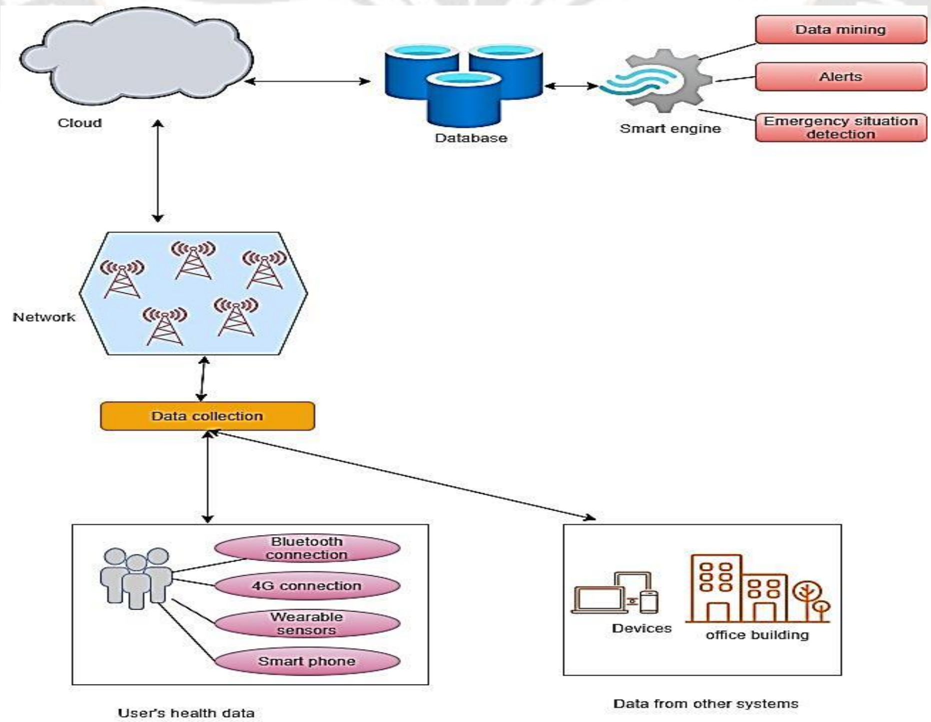

Fig1. Proposed Architecture

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The proposed e-health system should include a variety of sensors that can track things like gait; body temperature, respiration rate, and gait, among other things (see Fig. 1). The sensors utilized will be decided by the people being observed and their circumstances. For this purpose, however, only external sensors will be examined. It's possible that the sensors will need to be placed in various body parts.

The system creates two types of information: routine and alarming data. People's medical parameters are included in the usual data. The energy consumed in the network is optimized in the proposed method.

Calculating the function values at a series of evenly spaced places brackets the optimum of a function. Typically, the search starts with a lower bound on the variable and compares three successive function values through time based on the assumption that the function is unimodal. The search is either discontinued or continued based on the results of the comparison by changing one of the three points with a new point.

The main objective is to minimize energy consumption. To calculate the energy consumed in the network it is required to calculate total time taken and transmission power.

Table1. Parameters and description

Parameters	**Description**
T_t	*Transmission time*
T_r	*Remote execution time*
D_s	*Data size*
$R_{i,m}$	*Data rate*
$\mu_{k,m}$	*Task offloading from k to m node*
α_k	*Task offload to cloud*
$P_{k,m}$	*Transmission power from k to m*
$F_{k,m}$	*Small scale fading between k and m*
$\mu_{i,m}$	*Task offloading from k to m node*
α_i	*Task offload to cloud*
$P_{i,m}$	*Transmission power from k to m*
$F_{i,m}$	*Small scale fading between k and m*
σ	*Standard deviation*

Total time,

$$\mathrm{T} = Tt + Tr \quad (1)$$

Transmission time,

$$\mathrm{Tr} = \frac{\mathrm{Ds}}{\mathrm{Ri,m}} \quad (2)$$

$$\mathrm{Ri,m} = \sum_{k,i=1}^{n} ((\mu\mathrm{k,m}\ \alpha\mathrm{kPk,m}|\mathrm{Fk,m}\ |2 + \mu\mathrm{i,m}\alpha\mathrm{iPi,m}|\mathrm{Fi,m}\ |2) + \sigma 2) \quad (3)$$

Remote execution time,

$$\mathrm{Tr} = \frac{\mathrm{Cu}}{\mathrm{Cr}} \quad (4)$$

Energy consumed,

$$\mathrm{Ei} = T * Pi \quad (5)$$

3.1. Algorithm

Let A_i be the tasks and E_i be the energy consumed for different tasks. Let E_{imin} be the lowest value among generated values and E_{imax} be the highest value among all the values.

Now, assign a = E_{imin} and b= E_{imax}. This represents lower and upper boundary.

Input: Data size, Number of users, CPU cycles, computation speed, transmission power

Output: Optimized energy

Objective: To optimize energy consumed in the network.

Step1: Calculate total time,

$\mathrm{T} = Tt + Tr$

$\mathrm{Tr} = \frac{\mathrm{Ds}}{\mathrm{Ri,m}}$

$\mathrm{Tr} = \frac{\mathrm{Cu}}{\mathrm{Cr}}$

$\mathrm{Ri,m} = \sum_{k,i=1}^{n} ((\mu\mathrm{k,m}\ \alpha\mathrm{kPk,m}|\mathrm{Fk,m}\ |2 + \mu\mathrm{i,m}\alpha\mathrm{iPi,m}|\mathrm{Fi,m}\ |2) + \sigma 2)$

$\mathrm{Ei} = T * Pi$

Step2: Set a = E_{imin}, b= E_{imax}

Step3:

Δk =(b-a)\n; K1=a; k2=k1+Δk; k3= k2+Δk;

Step4: If f(k1)>f(k2)<f(k3)

Output minimum point is between (k1, k3)

End

Else

K1= k2; K2 = k3; K3 = k2+Δk;

Step5:

If k3< b

Go to step4

Else

Output no minimum point exist

End

4. RESULT EVALUATION

The proposed algorithm is implemented in cloud simulator. The total energy consumed in the network is calculated by using total time taken to process the request and transmission time.

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Table 2. Energy consumed by varying number of users

Number of user's	**Energy consumed(Joules)**	
	Existing	**Proposed**
10	1.4	0.4
20	3	1.5
30	6	2.7
40	9	3.8
50	10	5.2
60	11	5.9
70	11.5	6.3
80	12	7.5
90	12.2	7.9
100	12.5	8.4

Table 3. Energy consumption by varying Data size

Data size(MB)	**Energy consumed (mJ)**		
	STO	**TCO**	**Proposed**
10	480	440	180
15	510	450	250
20	530	480	310
25	550	510	390

Table 4. Energy consumption by varying computations

Computations per task(in Megacycles)	**Energy consumed (mJ)**		
	STO	**TCO**	**Proposed**
20	520	410	320
30	710	625	580
40	1000	840	665
50	1250	1050	890

The obtained energy is then optimized using the proposed algorithm. The experiment is implemented with 10 users and increased to 20, 30, and so on up to 100. The energy consumed is represented in the table and graph given below. From the results it is observed that for 10 users with server's computation capacity 2.5 GHz, data size 50Mb the energy consumed is 0.4J, for 20 users it is 1.5J, for 40 users it is 3.8 and for 100 users it is 8.4J. The energy consumed is

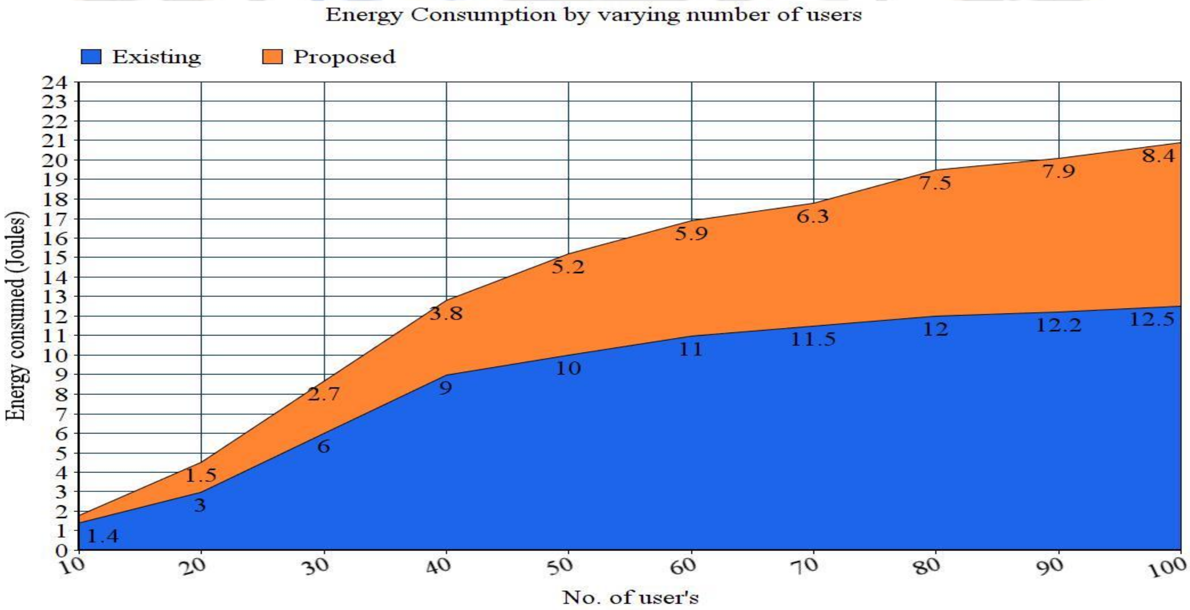

Fig2. Energy consumption for different user's

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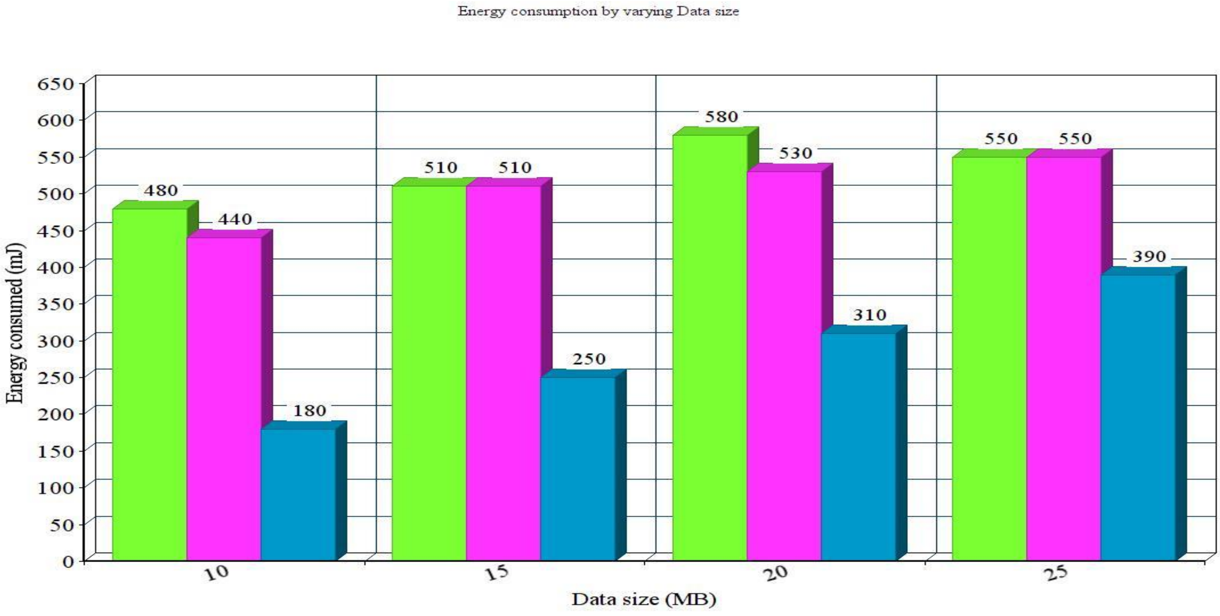

Fig 3. Energy consumption by varying Data size

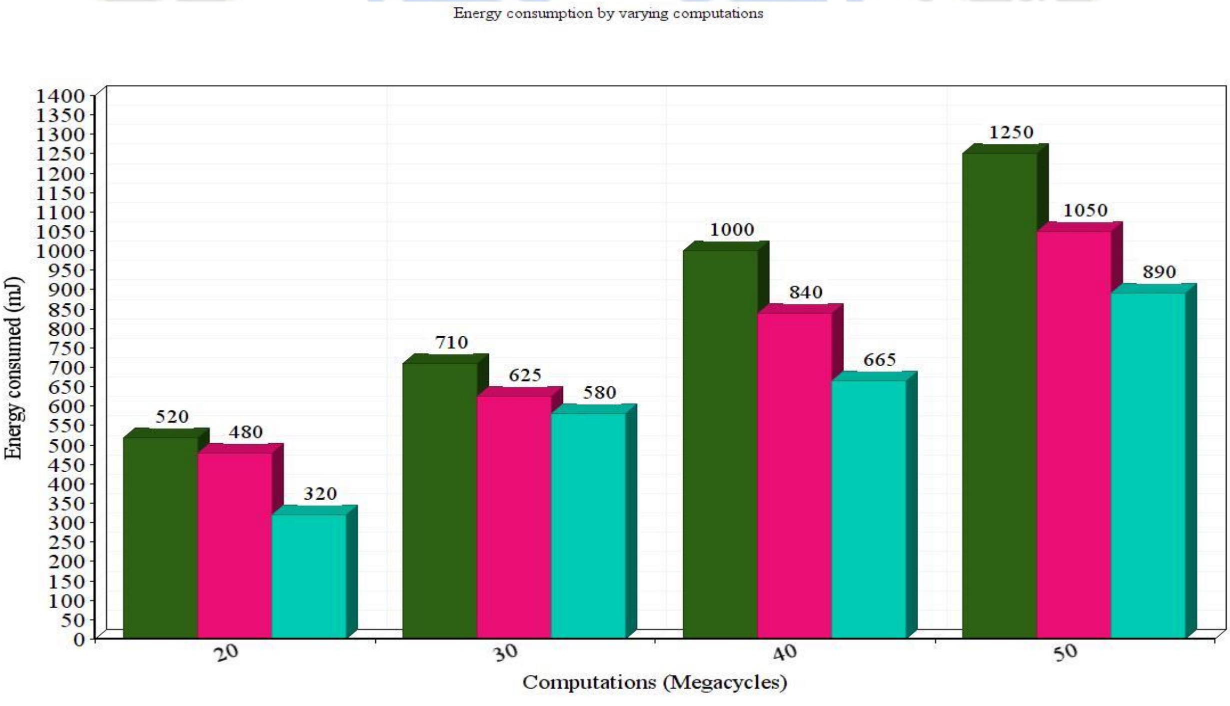

Fig 4. Energy consumption by varying computations

Increasing with the number of users but it is stable compared to existing approach. In the existing approach the energy consumption has increased drastically in the beginning and has remained stable after certain period. Overall the performance of the proposed approach has been increased by 57.89% when compared to existing approach.

The algorithm is implemented by varying the input task's data size. The data size was initially set to 10MB. The input consumes 180mJ of energy to process. STO and TCO [27] are 480mJ and 440mJ, respectively, for existing approaches. The method was tried with different data sizes such as 15MB, 20MB, and 25MB. Table 3 shows the

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amount of energy consumed. The overall performance of the proposed approach has been increased by 21.9% compared to existing algorithms.

The approach is implemented using different computations for different tasks. The algorithm was first tested with 20 megacycles. The input requires 320mJ of energy to process. STO and TCO are 520mJ and 480mJ, respectively, for existing approaches. Different values of 30 megacycles, 40 megacycles, and 50 megacycles were used to test the process. Table 4 shows the amount of energy consumed. The overall performance of the proposed approach has been increased by 59.09% compared to existing algorithms.

5. CONCLUSION

Internet of Things (IoT) and Smart cities represents the future. To make the city more sustainable and secure, a combination of several systems focused on monitoring multiple aspects of the smart city (such as water, e-health, power monitoring, air quality monitoring, gas, and emergency scenario detection) can be used. The energy consumption plays a vital role in the smart cities particularly for e-health. An optimization method is proposed by varying the lower value and higher value of obtained energy. The algorithm is implemented by varying number of user's, data size and computations per task. The energy consumed in the network is minimized compared to existing method and overall performance is increased by 57.89%.

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