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Original Research Article

Using cloud computing to increase authentication and security in an IoT-enabled cancer predicative model

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ABSTRACT

Cloud computing, machine learning, the Internet of Things, deep learning, and artificial intelligence are used in a variety of areas, including healthcare, transportation, smart cities, and agriculture, to create beneficial results for a variety of challenges in today's world. This paper focuses on one of these applications in the cloud computing and IoMT domains. Several sensors were implanted in the human body to gather patient-specific information, such as body measurements temp deviations, and many other factors that contribute to changes in blood cells that develop into malignant cells. The major goal of this project is to create a cancer prediction system that uses the IoT to extract information from blood results in order to determine whether they are normal or abnormal. Furthermore, the findings of cancer patients' blood tests are encrypted and saved in the cloud for quick access by a doctor or healthcare worker through the Internet to handle patient data in a secure manner. The AES technique is used for encryption and decryption in order to offer authentication and security when dealing with cancer patients. Because all of the required cancer treatment information is stored on the cloud, the main focus is on properly handling healthcare data for patients while they are away from home. Using virtual machines, the work completion time is decreased from 450 to 170 min. Simulations are used to test the proposed model's performance, and the results show that it outperforms alternative options significantly.

Keywords: the Internet of Medical Things (IoMT); cloud computing; encryption security; cancer prediction system

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1. Introduction

IoT is gaining traction in different fields, including transforming a regular city into a smart city, transforming the transportation sector into an IoT-enabled transportation field, transforming hospital administration into a healthcare system, and so on. It's also widely accepted that the IoT occurs everywhere there are sensors to gather, analyze, and store data[1]. New studies in the healthcare system have focused on numerous sensors that are implanted in the human body to anticipate heartbeats, blood pressure, and variations in the functioning of human body components[2].

IoMT is a subset of the Internet of Things that is primarily concerned with healthcare systems and the remote resolution of medical-related concerns such as patient identification, illness diagnosis, and data storage in the cloud[3,4].

Wearable sensors, network devices, and smartphones are among the components that collect the patient's vital signs[5]. The medical data is then sent via the 5G network to control database servers. Medical professionals acquire the stored data and do some analysis on it in order to make suitable treatment decisions[6,7].

IoT refers to any imitative or regular system that has been issued an IP address and the capacity to transport data throughout the system is referred to as IoT. The Internet of Things has progressed in tandem with the information era[8]. The Web of Things Cloud Service enables superior communication between sensors in the Internet of Things (IoT), which is commonly considered the most significant network; billions of linked objects and machines will soon join human customers[9].

The question remains, though, as to how the gadgets will remain connected throughout[10]. The network, which is referred to as the web of things cloud administration, determines the right reaction. More widespread use has served as a catalyst for the development and dissemination of flexible Internet of Things apps and action plans. Distributed computing and the Internet of Things (IoT) have become two inextricably linked future web propellers, with one paving the way for the other. The intermixing of IoT and cloud figuring has resulted in a variety of areas of interest[11].

Providing infrastructure: IoT in the Cloud provides open cloud administration that may help the platform by granting outsiders access to the system. As a result, the integration will benefit IoT data or mathematical segments that function on IoT devices.

Expanded scalability: IoT devices require a large amount of storage space in order to share data for critical tasks. IoT in the cloud, such as Stonefly Cloud in conjunction with Microsoft Azure, may give clients with progressively greater scope that can grow in response to consumer demand. It is commonly referred to as resolving customer's limit demands.

Pay-as-you-go: Internet cloud computing foundations assist the Internet of Things in giving greater weight to the rising considerable amount of data supplied.

Extended performance: IoT devices create large quantities of data, which need good translation in order for them to collaborate and communicate. IoT on the cloud provides the required accessibility for exchanging data between devices and fast acquiring centrality.

Clients are not under any need to purchase additional notable or limited space. With Internet cloud computing, they can't increase capacity as data grows, and they must pay for the storage space they use. The World Wide Web is made up of a vast number of private, open, academic, corporate, and government websites from all over the world, as well as a wide variety of information resources and organizations. Distributed computing is defined as a method for using a shared pool of adaptable preparation resources, such as frameworks, servers, storage devices, and organizations, that may be immediately given and released with minimum organization effort or expert coordination effort.

Cloud computing, like a utility over a framework, focuses on dispersing benefits to obtain insight and company scale. Cloud computing is a method of calculating that relies on servers and apps sharing processing resources, and it has evolved into a new paradigm for enabling and transferring authority via the Internet. The cloud is also focused on increasing the capacity of shared resources.

Cloud computing helps companies to keep a strategic distance from upfront framework expenditures and endeavors, allowing them to get their applications up and running faster and with less upkeep. To provide ideal administration to mobile clients, portable dispersed computing combines cloud computing and cell phones. This study focuses on the day-to-day operations of the health-care business[11]. The current health-care sector is beset by problems with calculations and processing. The traditional healthcare business has several problems, including limited physical storage, security and privacy, and medical errors.

Patients' records include sensitive information that must be safeguarded at all times. The current system has a lot of discrepancies when it comes to securing patient data. It is inefficient to keep medical data since it takes up more memory space.

Cloud computing is becoming increasingly important in the rapidly changing world of computers, particularly in the health-care business. Cloud computing allows internet-connected devices to access healthcare data from anywhere in the world. Furthermore, medical practitioners may exchange their resources and medical knowledge with other world-renowned experts in the same sector. The goal of this project is to improve the current health-care industry's performance and operations[12].

A system structure gave birth to the name "Cloud". As cloud form, system experts are used to communicate with various devices and their interconnected networks. The basic approach to dealing with this cloud system plan is depicted in **Figure 1**. Cloud computing is built on a mix of old and new ideas from a variety of disciplines of study.

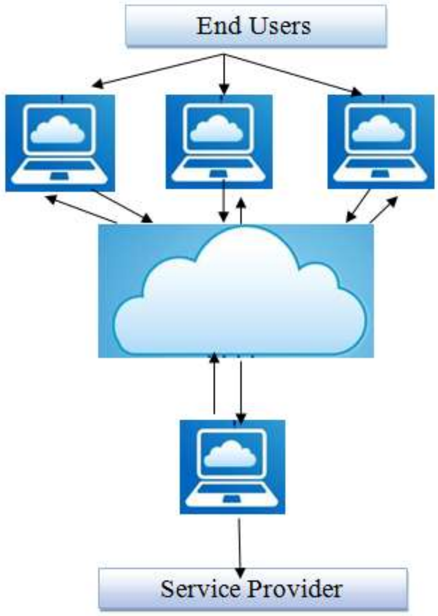

Figure 1. An overview of cloud storage.

Distributed computing refers to processing that uses pooled computer resources rather than local servers or individual devices. **Figure 2** shows an overview of IoT and cloud computing, including data collected from various sensor devices, actuators, and all other connected IoT systems, cloud storage to store the data, a dashboard interface, a logic configuration interface, and a rule engine for logic and data analysis.

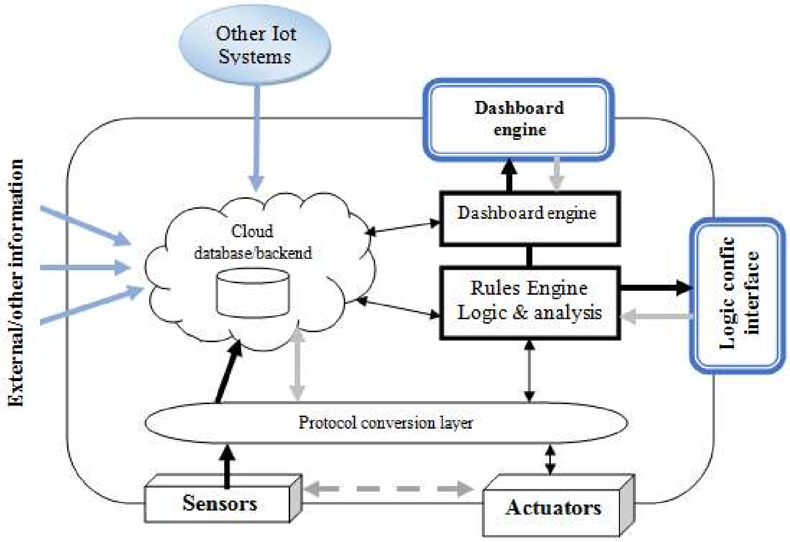

Figure 2. An overview of an IoT system with a cloud database.

The major components and characteristics of cloud computing are depicted in **Figure 3**, which contains the services that are required in order to use cloud storage.

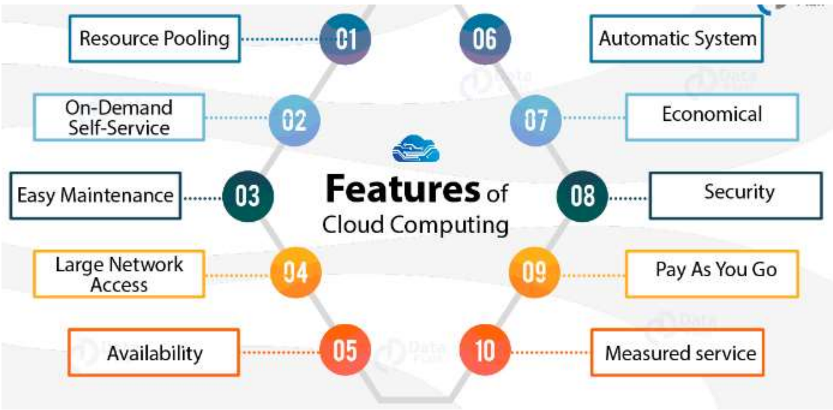

Figure 3. Features of cloud computing.

The major goal of this paper is to create a smart, integrated IoT healthcare system for cancer treatment. This system employs an IoMT system in conjunction with the cloud to monitor patient information in the medical area. We want to show how IoT-based health care systems have evolved, such as in an e-healthcare system. Patient information such as the patient's name, age, marital status, residence, phone number, blood pressure, past medical history, and heart rate deviation, is gathered utilizing different sensor devices implanted in the patient's body.

Then, for security and authentication, it is determined to remove the cancer patient's blood test report information, which will be encrypted and kept in cloud storage. It is desired for a healthcare doctor to access a patient's cancer data over the Internet at any time and from any location. **Figure 4** depicts the various benefits of adopting cloud storage.

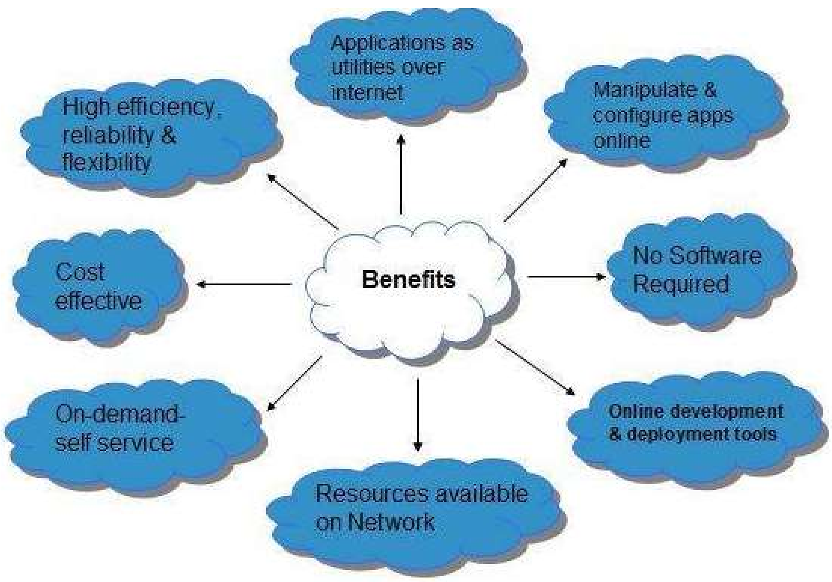

Figure 4. The benefits of cloud storage.

2. Motivation and related work

Without a doubt, the worldwide burden of cancer incidence has increased to record levels, having doubled between 1975 and 2000[13]. It is also predicted that by 2020, the number will have doubled again, and by 2030, it would have almost quadrupled. However, research and development efforts to minimize the disease's threat have increased across the world, with the goal of ensuring a cancer-free population while increasing quality of life. This, however, does not come without a cost. It's incredible to learn that a significant amount of money has been spent on cancer therapy research and development, with millions of dollars being invested annually.

For example, in 2015, $480.2 million was funded in cancer research in Canada alone, a small decrease from 2011[14]. Given the foregoing, the goal of better cancer care delivery has inspired and spurred this study Endeavour. There is no better time than now to supplement existing treatment choices by using the benefits of IoT technology via embedded smart linked devices and sensors in cancer care services.

Through system architecture that facilitates health region-wide connections, this relatively recent trend in IoT technology will suffice in guaranteeing interconnection and interoperability across health centers, clinics, and hospitals in diverse areas. Increased patient-doctor-nurse experiences, lower expenses, total income potential[15], improved ROI, greater business model[16], and improved cooperation with health practitioners and patients[17] are all apparent benefits of IoT.

The components of the cloud model are categorized according to Lee[2] cloud control server, an authentication server, an application server, and asset revelation are all examples of cloud control servers. Controlling resources, inspecting computers, utilizing virtual machines, and allocating storage space are all tasks that the cloud controller is responsible for. Approval implies that each client has a verifiable reputation. This is necessary in view of the fact that a few benefits may be provided only to specific consumers or specific types of customers. Customers will be able to utilize distant resources if resources are identified. Customers access distributed computing via coordinated client devices such as PCs, tablets, workstations and smart phones. Many of these devices, known as cloud clients, trust on distributed computing for all or a large portion of their programmers, rendering them practically useless without it. Many cloud apps don't require explicit client code; instead, users communicate with the cloud application using a web browser. **Figure 5** shows the cloud-based rural e-healthcare system, while **Figure 6** shows the rural healthcare information model.

Padhy et al.[18] developed a strategy for minimizing the amount of time and effort needed to build a medical services IT application in an emergency clinic. Via a request basis, patients can view their medical records and treatments on their mobile phones. It may also be used to communicate data in a faultless and consistent manner between devices and various associations. Ramaswamy et al.[19] developed a method for ensuring cloud reliability. This architecture is made up of the cloud broker, who is considered as a trustworthy third party, the customer, and the cloud service provider (CSP). Customers' messages are encrypted to protect them from cyber-attacks.

Varalakshmi and Maheshwari[20] suggested a cloud-based cost-optimized resource utilization method. As part of the cloud computing system paradigm, the virtual machine repository and service provider have been portrayed. A job pool is used to hold various jobs that are supplied by clients. The job pool is retrieved using the best fit heuristic, and the jobs are then delivered to the appropriate virtual machine. In order to reduce power consumption, the authors combined the bin-packing approach with the virtualization idea. An

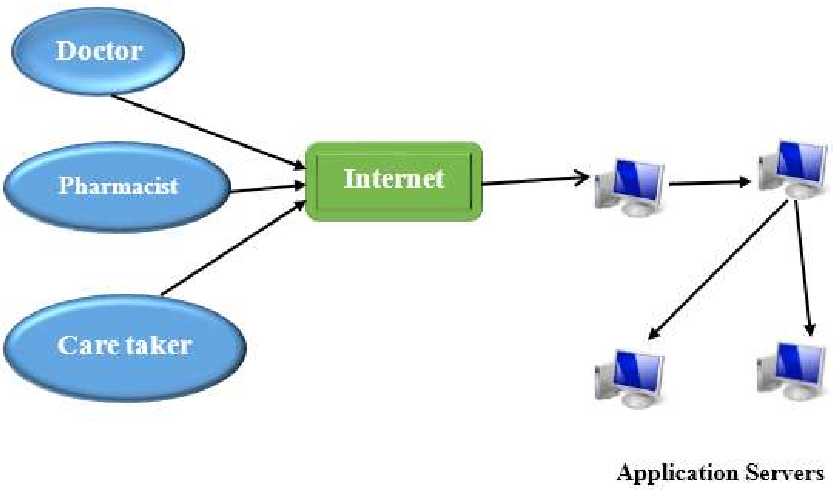

Figure 5. A rural healthcare system that runs on the cloud.

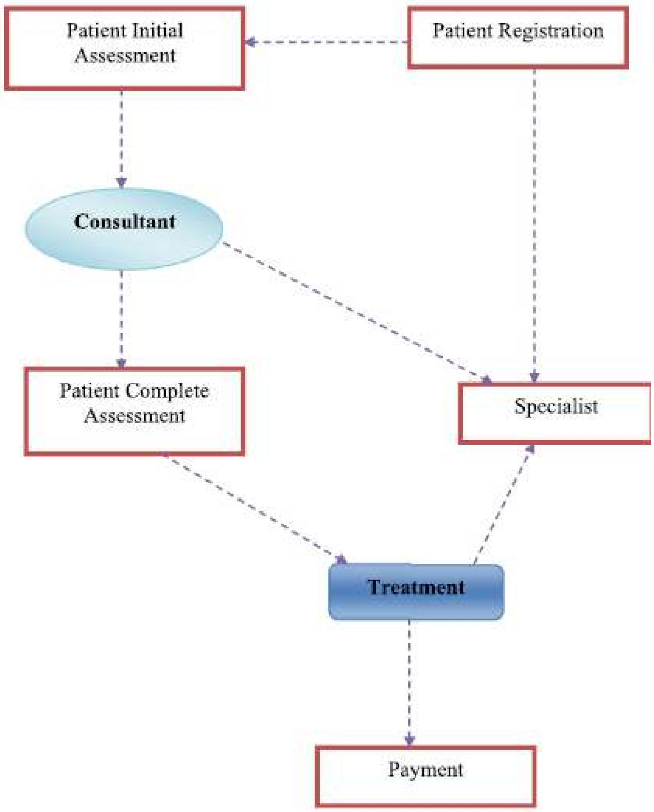

Figure 6. A model for an information system for rural healthcare.

algorithm for performing job replacement using a best-fit heuristic method is explored, as well as an algorithm for performing job replacement using a worst-fit heuristic approach.

According to Magaña-Espinoza et al.[21], WBSN is used to monitor people's heart rates and motion rates in their homes. When fast changes in measured values occur, the edge node connects to the internet and sends an alarm (by Smartphone) to family members or specialists (early detection of falls, tachycardia, or bradycardia). Similarly, Villarrubia et al.[22] suggest an ECG-based system for following patients at home and monitoring their heart function. A common television interface allows patients to engage with the system[23] investigates the use of Bluemix cloud technology to store physiological data, allowing clinicians remote access and visualization of the results of their analysis via the IBM Watson IoT platform, while Alwan and Prahald Rao[24] propose a case study of fever diagnosis using an embedded system that continuously monitors the patient's temperature.

Effiok et al.[25] proposed a prostate cancer care technique in the area of IoT. Risk predictive modeling has been used to summarize the concept of anticipating prostate cancer risk. To summarize the risk linkages, **Figure 7** depicts their entire system structure, which takes into account characteristics like age, family history, and geographic location to determine the quantity of vitamin D, animal fat, and diabetes mellitus. The authors provided a semantic description of the risk linkages.

Sridhar et al.[26] proposed a client-centric multitenancy paradigm with an algorithm for processing virtual machine client requests. As shown in **Figure 8**, the authors defined a three-tier architecture. Cluster priority was determined using the best fit approach.

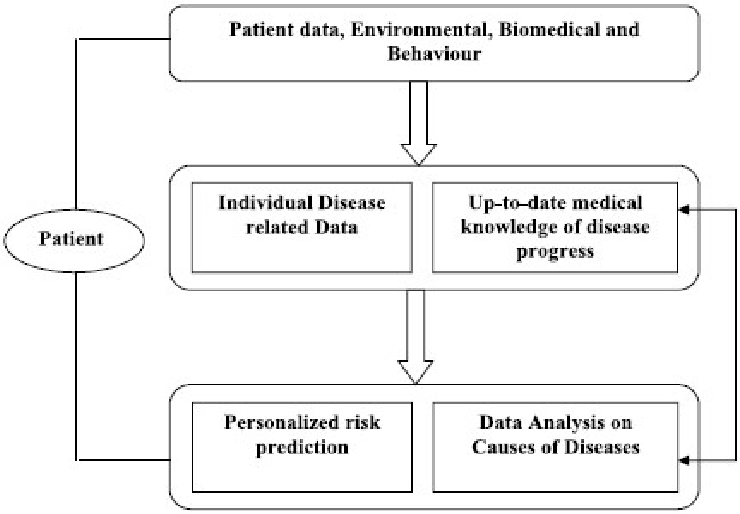

Figure 7. The treatment of prostate cancer.

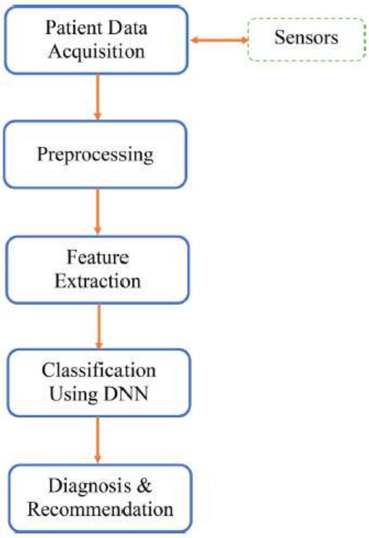

Figure 8. Architecture with three tiers.

Lloret et al.[27] presented an architecture and security protocol that allow data, network services, computation, and storage resources to be exchanged amongst linked mHealth clouds. The shortest path first (SPF) method is used in the routing algorithm. Furthermore, the suggested method is extremely scalable and keeps the cloud load balanced. It has been proven in performance testing to be a secure system architecture and a regulated transmission system.

The IoMT has demonstrated significant growth in the creation of medical applications and aids patients and medical teams, as seen by the discussion of related work. It gathers patient information and sends it to medical databases, where medical experts may access it and treat patients' illnesses. Many solutions have recently been presented to deal with data routing in healthcare systems; however, it has been shown that the majority of them are inefficient in terms of communication costs and data delivery reliability. According to the findings, the majority of solutions solely examine greedy heuristics based on the distance parameter, ignoring connection failures and channel latency factors. Furthermore, certain methods were found to offer consistent routing performance at the price of energy consumption and network load. Furthermore, critical patient data that might be exploited for illegal assertions must be safeguarded from network threats and maintained in its integrity. As a result, the security mechanism should be implemented in healthcare systems that have reliable data accessibility.

3. Cancer prediction model using IoMT with cloud

Figure 9 depicts a cancer prediction system that combines IoMT and cloud computing. Temperature and blood pressure are monitored using a variety of sensors implanted in the human body. These data are then stored using any local processing system and are considered real clinical information. This suggested method is very useful for predicting cancer, thus after recognizing the difference in blood cells and temperature, the blood test report or mammography report is utilized for processing. The features of a blood test report are retrieved for categorization since the features of a blood test might belong to a healthy individual or a cancer patient.

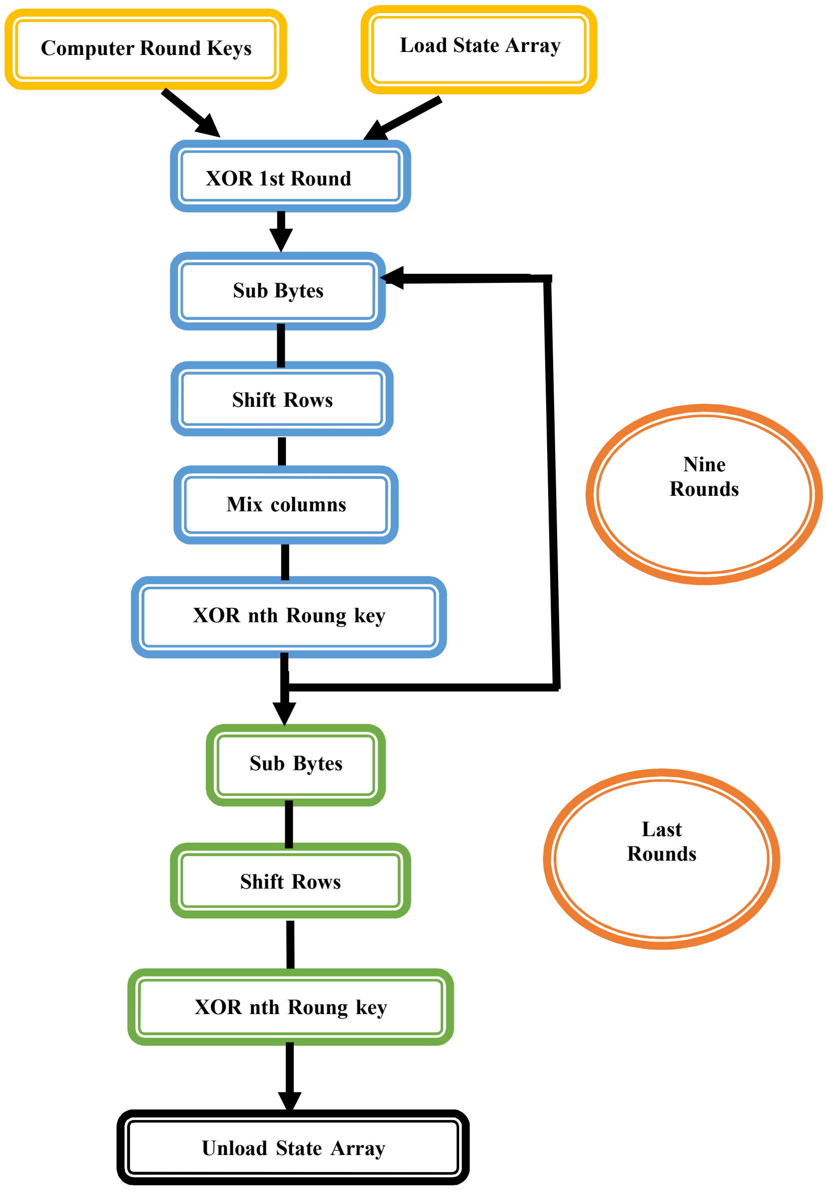

Figure 9. IoMT-based cancer prediction system flow chart.

For classification, any deep learning algorithm should be used, such as Alex net, VGG 16, or Google Net. The accuracy of various cancer types, such as breast cancer, lung cancer, and blood cancer, will be predicted by training the given neural network design. A blood test result or any other medical data is used as the input in this investigation, which is subsequently encrypted using the AES method to produce authenticated encrypted data[9]. Since every patient might migrate from his or her hometown for any reason, this encrypted cancer information is saved on the cloud to improve the performance of the e-healthcare system. The patient does not need to request that the treatment details be followed and continued in the hospital if the data is kept on the cloud. He or she may immediately access cloud-based e-healthcare data, which can be accessed at any time and from any location without delay or significant processing[28].

The Advanced Encryption Standard is a well-known and widely recognized symmetric encryption computation that is likely to be encountered these days (AES). AES does all of its calculations in bytes, rather than bits. As a result, AES treats a plain text block's 128 bits as 16 bytes. For grid preparation, these 16 bytes are divided into four parts and four columns. AES is based on replacement and permutation plan standards, as well as a mixture of the two, which is more efficient in terms of programming and equipment. In contrast to DES, AES has a configurable number of rounds determined by the key length. For 128-bit keys, AES uses 10 rounds, while for 192-bit keys, it uses twelve rounds.

The following is a description of the Advanced Encryption Standard (AES)[29]:

- AES operates by repeatedly rehashing the corresponding steps described;
- AES is an encryption algorithm that uses a secret key;
- AES is limited to a certain amount of bytes.

The characteristics of AES are as follows:

- Symmetric block cypher with symmetric key;
- Data in 128 bits, keys in 128/192/256 bits;
- Triple-DES is more secure and quicker;
- Information on the design and specs;
- Software written in C and Java.

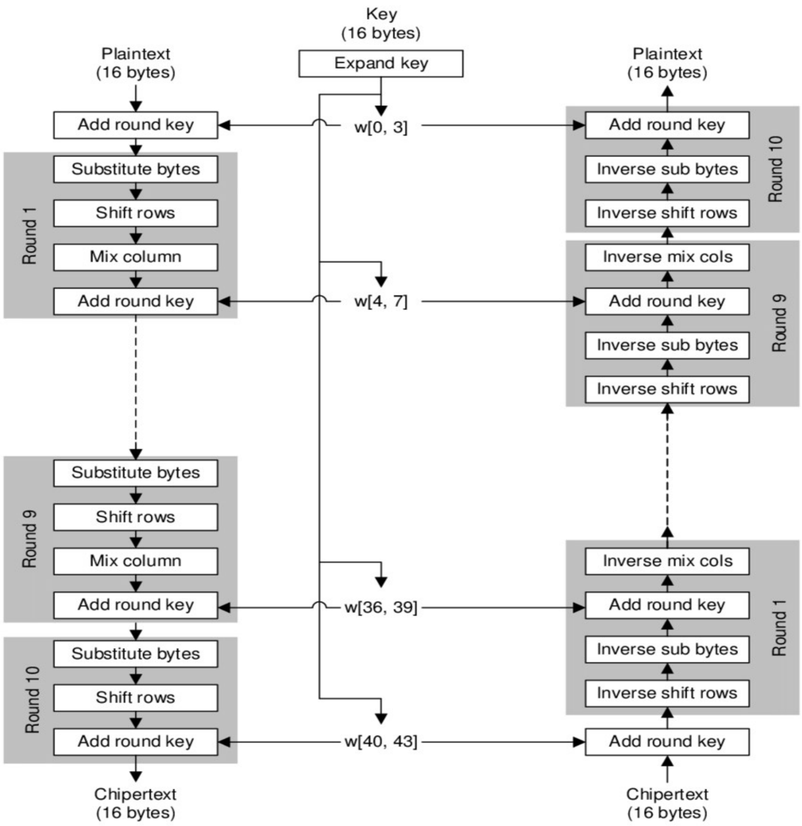

Figure 10. The process of AES encryption.

Figure 10 depicted efforts in the AES encryption process, whereas **Figure 11** depicted the basic structure of AES.

AES encryption endeavors for a 128-bit square:

- Deduce the round key arrangement from the cypher key;

- Begin with the block information and then go on to the state exhibit (plaintext);
- In the starting state array, add the underlying round key;
- Finish nine rounds of state administration;
- Execute the tenth and final round of state operations;
- Make a copy of the last state array as the encoded data (cipher text).

Figure 11 shows an encrypted blood test result for a cancer patient that is stored in the cloud.

Figure 11. The basic structure of AES.

4. Results and discussions

The findings are simulated using the CloudSim environment. The cloud environment is depicted in **Figure 12.** Cloud computing is well suited to applications with diverse, dynamic, and competing quality of service (QoS) requirements. Different applications have different execution levels, outstanding burdens, and dynamic application scaling requirements, but when we use the cloud to host apps, these attributes, administration models, and organizational models create an ambiguous situation. Complicated attachments, transmission, and organization are all necessitated by the cloud.

Figure 12. CloudSim environment.

CloudSim is a well-known toolkit for simulating and reproducing cloud processing settings. It provides the cloud figuring components with a structure and social exhibiting. Simulation of cloud scenarios and applications for performance evaluation gives useful insights into such strong, widely communicated, and adaptable conditions.

The following are the main benefits of simulation:

- Adaptability in describing designs;
- Convenience and flexibility;
- Cost savings.

CloudSim is simple to use and just requires a basic grasp of Java programming and a few cloud computing concepts. It is also beneficial to learn how to use programming IDEs such as Eclipse or NetBeans. Because it is a library, CloudSim does not require installation. Most of the time, you can unload the downloaded bundle in any registry and then upload it to the Java Classpath to use it. Modeling cloud resources and the number of brokers required was used to create Cloud Example 3. The successful development of cloud resources. The cloudlet was represented by the broker in the CloudSim environment, coupled with the necessary data centre construction in **Table 1**.

Table 1. Time taken for VM.

Cloudlet ID	**0**	**2**	**3**	**0**	**0**	**1**
Status	Success	Success	Success	Success	Success	Success
Data Center ID	2	2	2	2	3	2
VM ID	0	1	0	0	0	1
Time	400	80	160	160	160	200
Start Time	0.1	0.1	0.1	0.2	0.2	0.1
Finish Time	400.1	80.1	160.1	160.2	160.2	200.1

These results can be used as a basic database for medical practitioners to utilize for free in their study.

5. Comparison of the proposed system with other similar systems

In order to emphasize the originality of our study, we conducted a comparison between the recommended solution and some other current solutions in the areas of cancer care services and business analytics, as mentioned later. We compared the actors/parameters listed below, which are thought to be relevant to the application of IoMT in healthcare: IoMT devices, IoMT access technologies, GPS location tracking, routing protocols, analytics and cloud services, operational challenges, security, scalability, reliability, and other relevant parameters.

Table 2 demonstrates the originality of this paper, particularly when considering the level of complexity, security, dependability, stability, difficulties, and services involved. We must admit that the design architecture concept of the Smart Integrated IoMT Healthcare System for Cancer Care has proven promising as we advance from reactive to proactive healthcare.

Odeh et al.[30] describe the exception which analyzes the use of smart phone health applications to manage cancer patient care as an emerging technology for optimizing cancer care; all of the publications focus on IoT applications in healthcare.

Mobile applications are used to manage, support, and report adverse effects and symptoms connected to chemotherapy, as advised by mHealth[31], on the other hand, emphasizes the use of IoT and big data analytics in healthcare monitoring systems to assist physicians in making crucial health decisions based on vast amounts of data given by IoT-connected devices.

As a consequence, cloud services for real-time patient health alerting to physicians have been integrated, boosting evidence-based healthcare[32] focused on the use of wearable and mobile applications to improve patients' quality of life through improving work processes, productivity, cost reduction, inefficiencies reduction, and customer experience enhancement through the use of wearable and mobile apps. Despite the usage of Internet of Things (IoT) technology, each piece presents a unique perspective. However, due to the high number of heterogeneous devices, we can affirm that our proposed system takes use of a variety of IoT-enabled devices, as previously stated.

It also employs a variety of access technologies and communication criteria to ensure the delivery of trustworthy services, which are only mentioned in passing in other publications. Only this research and one other publication employ GPS location monitoring as a criterion. In summary, our proposed method appears to cover all cancer-related services, whereas other approaches appear to cover only a broad variety of healthcare services. Even the one that discusses how to improve cancer treatment employs mobile health technology rather than the Internet of Things to achieve its goal.

Table 2. Comparative analysis of the proposed system and related systems.

#	Factor	Cancer prediction model using IoMT with cloud.	The Internet of Things in Medical and big data in healthcare[32].	Medical Internet of Things and big data analytics of IoT-based health care monitoring system[31].	Using mobile health to improve cancer care[30].
1	**IoT devices**	Sensors, actuators, WBAN, WSNs, IoT-medical devices, wearables, RFID, wrist bands, etc.	Wearable (such as blood pressure, ECG, and glucose level), heart rate sensors, cell phones, and mobile applications are all examples of this.	IoT health sensors and a variety of sensors, including SpO2, moisture, cardiac rate, wearable, and so on.	Mobile devices, such as smart phones and tablets, as well as mobile apps.
2	**Cancer care services**	The topic of cancer care as a whole, as well as treatment alternatives, was extensively discussed. There are no particular cases cited.	Nothing is covered, with the exception of healthcare wellness and treatment. Only a cloud service for cancer research was suggested in relation to the collaborative cancer cloud platform.	No specific services are covered, with the exception of healthcare monitoring based on personalized healthcare.	Cancer services, where mobile health is used to improve cancer treatment and better meet patient demand (m-health).
3	**Access technologies for the Internet of Things**	NFC, ZigBee, BLE, LPWA, Wireless HART, 6LoWPAN, IEEE wireless cellular, Lora WAN, 802.15.4.	Not Specified	Galileo Gen2 is being utilized as an Internet of Things (IoT) agent for cloud services. Other data transfer methods include GPRS/GSM, 3G, UDP, and I2C using a SIM card.	Bluetooth, 3G and 4G Mobile wireless connection.
4	**Tracking your location with GPS**	Utilized	None	None	Utilized
5	**Cloud computing and analytics**	Analytics in business and data, cloud platforms, cloud computing, Hadoop development framework, and so on.	Through cloud services, big data analytics and the Hadoop architecture can be used to gather information for real-time decision-making and evidence-based medicine.	Health data is managed and shared through cloud services. For big data analytics, the Hadoop framework and MapReduce are employed.	Mobile phone voice and texting services are used. There is no big data.
6	**Security**	WSN, smart devices; IPv6; sensor privacy and encryption; medical records and services, and so on.	None	None	None
7	**Scalability**	In the core, distribution, and access layers, hierarchical architecture is used.	None	None	None
8	**Other relevant parameter**	Framework for IoT health systems, WSN routing, network architecture, and so on.	The capabilities of the platform are discussed, as well as how CRM and Sales force may be used to bridge the gap between patient medical data and pharma data.	It was stressed that huge data processing should move away from symmetric multiprocessing (SMP) and toward massively parallel processing (MPP).	Side effects are managed, medicine adherence is supported, cancer information is provided, planning and follow-up is done, and cancer is detected and diagnosed.

6. Conclusions and future work

Because IoMT and cloud computing are so intertwined, IoMT is regarded as a fascinating research topic when coupled with cloud computing. The application of IoMT and cloud computing in e-healthcare systems, namely cancer disease prediction, is the emphasis of this research. IoMT is used to collect and process cancer patient data, and the sensitive data is encrypted using the AES technique before being saved in the cloud. The data from a cancer patient's blood tests was encrypted and then elaborated using an IoMT-based cancer prediction system. The major objective of this research is to improve the security and flexibility of accessing cloud-based cancer patient data.

CloudSim is a software application that simulates outcomes and stores encrypted cancer patient data on the cloud. Using any deep learning technology, breast cancer, lung cancer, blood cancer, skin cancer, and other malignancies will be examined and forecasted in the future.

In brief, this study would enhance or supplement existing cancer treatment options or strategies by utilizing the potentials of the IoMT/WSN combination, as we have proposed, to save lives and improve and raise quality of life through the use of smart connected devices. Finally, in order to show the research's uniqueness, we compared the proposed IoMT-enabled healthcare system to a few other similar systems.

Finally, numerous services are available in healthcare settings, but we've just covered cancer treatment and business analytics cloud services thus far. As a result, new services will be considered and included in our future study efforts on the same subject topic.

In future work, we will present recent advancements in therapeutic response prediction using machine learning, which is the most widely used branch of artificial intelligence. We describe the basics of machine learning algorithms, illustrate their use, and highlight the current challenges in therapy response prediction for clinical practice.

Conflict of interest

The author declares no conflict of interest.

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