Chapter 4
Cloud-Based Predictive Computing

4.1 Introduction

Recent advancements in the field of wireless and multimedia technology as well as computing, hold out promise to perform real-time communication in the various user-based sectors of health, transportation, media and education. The vision of the IoT and cloud computing is one such and provides real-time information to the connected users in the network. This advancement in technologies has led to the issue of data proliferation which in turn is responsible for data explosion and high cost of data processing. This exponential increase in data includes human data on the social media in the form of emails, photos, messages, blogs, tweets, digital data generated by sensors, such as GPS, the business data, the classified data to name a few. It is becoming difficult to store, query, analyze and share the data as the available data are huge in volume and highly complex due to the number of data sources and their interrelationships. The scope of the IoT-based cloud computing is significantly broad and includes the living and non-living entities connected to each other in the network. Making use of predictive computing over this large volume of data collected from various sensors nodes and stored in a cloud environment can be made more scalable, pervasive and easier to deploy using these advanced technologies. The cloud enables the business analytics to scale out the data easily and quickly, which in turn enables them to analyze data archive to identify the developing trends and leads to better customer satisfaction and profitability. Using cloud for predictive computing will make the computing resources delivered as a service and will provide multi-tenancy and shared resources this will also help in managing the issue of data proliferation. Various areas of opportunities can be achieved by using the cloud for predictive computing. Some of which are pre-packed cloud-based solutions, predictive modelling with the data in the cloud, and flexible compute power among many more. The advantages are scalability, pervasiveness, deployment agility, moving analytics to data, whereas the cons are complexity, privacy and security, regulatory issues and moving data to the cloud.

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Knowledge discovery and decision making are one of the major objectives of predictive computing. Big data computing poses a severe challenge in terms of the necessary hardware and software resources required for decision making. Hence, we look upon cloud technology as it offers a promising solution to this challenge by enabling ubiquitous and scalable provisioning of the computing resources [1]. In this chapter, we have explored the hybrid measure of IoT and cloud computing to predict the health status of a user by analyzing his/her physical activities at sustainable health centre of the smart city. It is considered that equipment in these sustainable health centres are equipped with sensors and continuously store the data related to the user's session in the cloud. This stored data is further utilized by the concerned healthcare professional for predicting the health status and in case, if any severe measures are required then alert is sent accordingly.

4.2 Related Work

Use of predictive computing from healthcare perspective is also increasing with the advancement of technologies. Various healthcare professionals and users are using a variety of ways and techniques for analyzing and predicting the health status. To perform prediction, data is collected from a variety of sensors like embedded sensors, wearable sensors and stored in the cloud for its further analysis and finding of patterns. Zhang et al. [2] also explained the use of the wireless sensor networks in healthcare in the future from a ubiquitous perspective and proposed a 3-tier system architecture for healthcare applications. They have also stated that with the technological advancements, the field of medical informatics has focused more on as well as emphasized the use of the Smartphones over wearable devices. Chen et al. [3] have presented the vision of IoT from the perspective of China and specified that in 'Remote medical monitoring' data can be collected from various sensor-like devices placed on an individual's body and once the data is processed advice can accordingly be given. In [4], Islam et al., have presented various aspects of the IoT-based healthcare technologies and stated that IoT can help any age group and address any disease in an innovative manner. In [5], Yang et al., have designed the home mobile healthcare system for wheelchair users. The proposed architecture utilizes the Smartphone for sending and receiving instructions from the source and sink nodes. In [6], Amendola et al., have used the RFID-based wearable tags to identify the movement of the body parts like arms, legs etc.; in fact, they have used the IoT for monitoring the information collected related to human lifestyles.

4.2.1 Cloud-Based Healthcare Frameworks

With the advancement in technologies, a number of cloud-based healthcare frameworks are being designed. Further, integration of clouds with IoT-and big data-based frameworks could provide several benefits of easy to deploy mechanism over traditional networks, enhanced information security during communication, quick access of records and energy savings over traditional existing healthcare frameworks [7]. In [8], Ghulam et al. have also focused on integration of cloud and IoT to have smart health solution. They have stated that convergence of the IoT and the cloud can render a wide application in daily and social life. It is because, IoT is a set of real-world small devices with limited processing power and storage capacity whereas the cloud can have huge storage capacity and processing power. Integration of IoT and cloud depicted by them is presented in Fig. 4.1. They have also identified various attributes like storage, accessibility, processing, distance, big data and security, where cloud computing can provide milestones achievements over IoT.

In [8], Ghulam et al. have also presented a health monitoring framework that captures voice, temperature, humidity, electrocardiogram of a patient using IoT technologies and at cloud side, main components are authentication manager, data manager, feature extraction server, classification server and storage. For authenticity, authors have embedded watermark into the signal. In [9], Tyagi et al. have proposed a cloud-based conceptual framework for implementing a cloud-centric IoT-based healthcare framework. Authors have built a network of various healthcare entities like patients, doctors, hospitals, etc. and used this network for safe transfer of medical information. In [10], Hossain and Muhammad have focused on real-time health monitoring infrastructure for analyzing patients. They have designed and presented a cloud-based healthIIoT framework to monitor ECG and other healthcare-related data using smart phones. Authors have also implemented the used the watermarking techniques for the security of data. In [11], Kashfia et al. have presented a healthcare framework known as 'Cloud-based MEDical system' (CMED) for developing countries. This CMED system consists of a portable health kit, WSN connection and tablet/Smartphone. CMED framework is shown in Fig. 4.2.

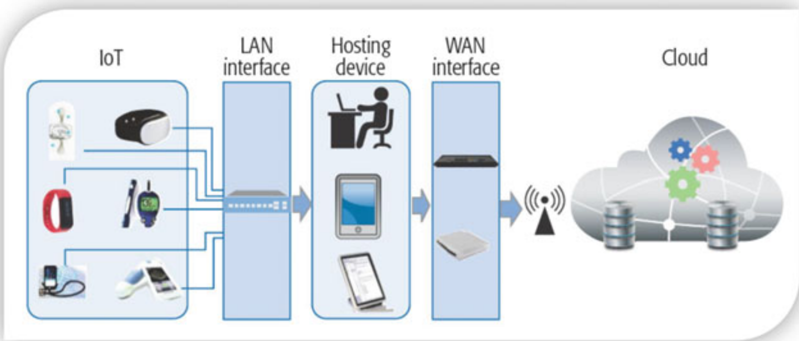


Fig. 4.1 Integration of IoT and cloud [8]

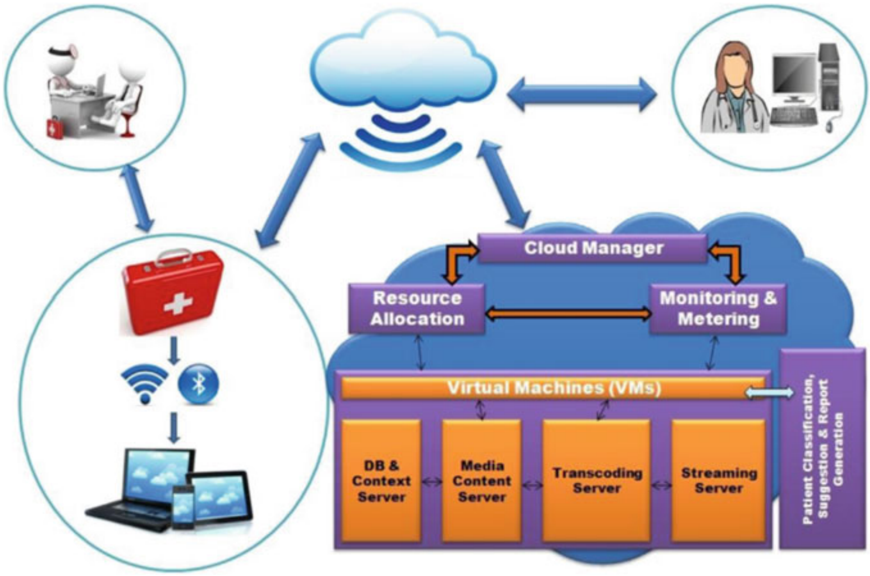


Fig. 4.2 CMED healthcare framework [11]

In [12], Nandyala and Kim have proposed an IoT-based architecture for u-Healthcare monitoring. They have also mentioned that traditional cloud computing architecture faces a lot of challenges and presented an extension of cloud as Fog. They have proposed a Cloud to Fog computing model for implementing the proposed architecture of healthcare monitoring. In [13], Kumar et al., have proposed a RFID-based intelligent authentication scheme in the healthcare using vehicular cloud computing. The authors have placed various tags and readers from users to road side units. Communication between these tags and readers are secured by elliptical curve cryptography-based key generation algorithm. In [14], Hassanalieragh et al., have presented the integration guidelines for remote health monitoring into medicinal practice. They have used smartphones as concentrator in IoT infrastructure and for aggregation of data, cloudlet's or clouds have been used. It is also realized that data processing could be done more efficiently using cloud rather that cloudlet's and wearable sensors have been used to collect the information. Authors have performed 2-3 days of continuous physiological monitoring using these sensors and collected related physiological parameters to update the relevant health database. In [15], Seales et al., have proposed an architecture for content centric networking for Health-IoT. This networking has several benefits and integrates health services and sensors, and clouds in Health-IoT. Proposed PHINet architecture automatically records the body data from user body sensors and further updates the database accordingly. Use of clouds in this architecture makes data easy to handle for analysis of both user and healthcare personnel. Wan et al. [16] have implemented the platform production services using IoT and inter cloud computing architectures. Proposed framework was used by vehicular networking applications. Authors have evaluated the performance of proposed system using probabilistic theory.

4.2.2 Predictive Healthcare Applications

Advances in sensor devices also lead to the development of predictive healthcare applications to be used by e-Health frameworks. Mobile healthcare which is also known as mHealth has only become possible because of this advancement in sensor technology and represents the new opportunities for mHealth-based predictive applications. A wide range of mHealth applications can be found for monitoring of Diabetes [17], Blood Pressure [18], Heart rate [19], Physical activity [20] and Anti-Obesity [21] like areas. There are varieties of healthcare applications available for various types of Smartphone, Tablets and iPad like devices and are known as BlueBox [19], WIHMD [18], AppPoint [22], Heart-To-Go [23], Instant heart rate [24]. Though various types of applications can be find over the internet but somewhere these applications lack in security and privacy, reliability, efficiency and acceptability.

Moreover, these applications are designed for Smartphone like devices where battery life is another issue. Figure 4.3a represents the healthcare application to monitor ECG using Smartphone, Fig. 4.3b shows the mobile application for monitoring of blood Pressure, heart rate, SPO2, Fig. 4.3c represents the capturing of blood pressure monitoring device data using smart phone and Fig. 4.3d represents the information of Glucometer using smartphone. These applications continuously check for the incoming data obtained by sensor for activities like heart rate, ECG, pulse, blood pressure and blood sugar levels of user and keep informing to the healthcare personnel in case of any emergency.

4.3 IoT-Based Cloud-Centric Design Architecture

From the previous discussion, we can observe that most of the proposed healthcare frameworks are over-optimized as they generate large amounts of data, and continuously send alerts to the users and healthcare personnel, which are of no use. Some of these frameworks and applications are designed to use the Smartphone for monitoring and capturing of data. In such a scenario, the continuous connectivity of the Smartphone devices is questionable. Keeping these shortcomings a priority, we have proposed the IoT-based predictive framework as shown in Fig. 4.4 which consists of the evaluation, implementation, feedback and security layers in the IoT environment for a cloud-centric communication between the user and healthcare personnel. IoT-based cloud computing framework architecture is applied for predictive analysis of physical activities of the users in sustainable health centres.

Fig. 4.3 Healthcare applications using Smartphones to monitor **a** ECG, **b** blood pressure, heart rate, SPO2 and body temperature, **c** blood pressure and pulse, **d** blood sugar level

The cloud computing framework provided a system which is embedded with intelligent sensors and devices rather than using smartphone sensors and wearable sensors to sense and retrieve data to store the information (value) of the general health-related parameters for individuals [25]. In this framework, IoT system includes a cloud centre for storing different data, public cloud centre, private cloud data centre and uses the intelligent services for providing the mechanism to secure the stored data and fast communication through intelligent devices. Finally, IoT-based cloud architecture is applied to perform the evaluation for its adoption, prediction analysis of physical activities, efficiency and related security. In the current work, the concept of IoT has been used with the proposed cloud-centric architecture to predict the user's physical activities at sustainable health centre of the smart city. Most healthcare personnel purport that if individual exercises

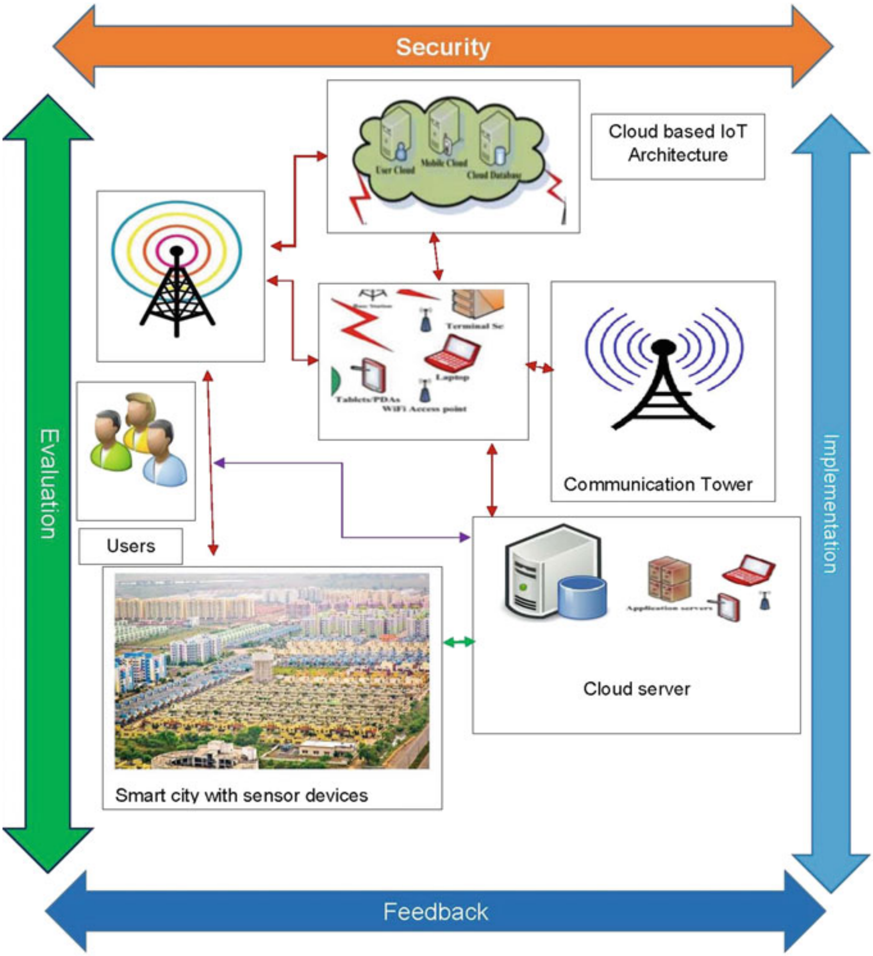


Fig. 4.4 IoT-based predictive healthcare framework for cloud-centric communication

regularly, then the complications and increase in the dosages of medications for diseases like diabetes, blood pressure and heart issues, can get postponed accordingly [26].

In Fig. 4.4, IoT-based cloud computing framework has been developed for providing the solution to individual users using smart devices. The system includes major phases for development of cloud systems. The system consists of the evaluation of sensing data and retrieving information, implementation paradigm, feedback phase and security phase in IoT-based intelligent sensors environment for a cloud-centric communication between the user and healthcare personnel. The basic methodology is applied to implement the IoT-based computing models or framework for the cloud-centric system for providing the efficient solution in the health sectors. The IoT-based cloud framework includes four different phases in the cloud system-based model. These phases are applied to cater the faster data processing and data communication between the individual and IoT-based systems (e.g. health assessment systems) [27]. The IoT-based computing models and methodology also can be applied to mitigate the redundancy and sparsity of massive amount of data which are necessary to be stored for analysis purposes. The four phases in this process are given as follows [26]:

(i) **Implementation phase**
The implementation phase depicts the overall framework architecture of IoT-based computing systems from the data acquisition, extraction of information, to data storage and analysis of data. It also uses the embedded intelligent sensors or devices in compression of any wearable devices or intelligent sensors by the individual.

(ii) **Security phase**
Security phase mainly emphasizes on IoT-related security issues and challenges on data storage and transfer extracted knowledge from data between source and destination intelligent sensors [28]. It also caters the better services for implementation of distributed system and cloud computing framework for various types of cloud servers (cloud database servers, data-centric server, database servers). The main objective of this phase is to implement the better security to user privacy preservation and security to user information.

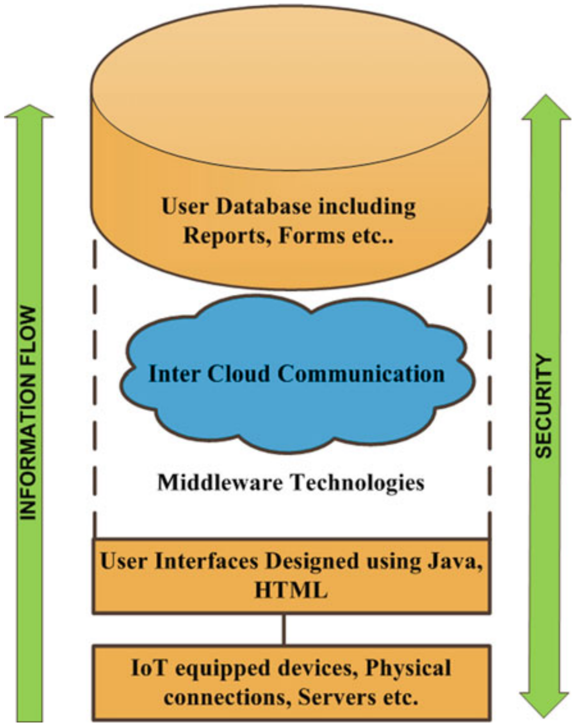
(iii) **Feedback phase**
In IoT-based cloud computing framework, feedback phase uses the results of the evaluation phase which are applied to revise the different applications. After each cycle of the performed application, the reported component or modalities are improved by doing rectification which assists to improve the overall performance of the IoT-based framework.

(iv) **Evaluation phase**
Evaluation phase is a phase which performs the functions of IoT-based computing and modelling systems by utilization of the different applications and to ensure a mitigation in the design complexity and its adoption to improve different services (e.g., healthcare services, agriculture monitoring services, traffic signal monitoring, transportation services, smart village-based services, medical services and information services between remote systems, etc.) [29].

4.3.1 Application Architecture

Application architecture for the IoT-based system proposed above reduces the complexity of the information storage, communication and enhances the performance of the overall healthcare system. The proposed application architecture is modified form of traditional 3-Tier architecture that represents the client-tier, business logic at middle tier and database at server-side. In the proposed application

Fig. 4.5 Application architecture



architecture [26], various web services and security services reside inside the cloud which are further implemented as a part of middleware technologies Fig. 4.5 introduces the multilayer application architecture which includes the IoT sensor devices, Treadmill equipment, application servers, base stations and handheld devices like PDAs, Tablets, notebooks, etc. at the bottom. These interconnected devices communicate with the user interfaces designed with JAVA. These user interfaces are responsible for capturing the information from the connected sensors of the treadmill equipment at the end of the user session and any further update of this information with the cloud servers. These user interfaces are further connected via the middleware with many Cloud Servers and support the inter cloud communication with cloud database. In middleware technologies, XML web services can be used to carry secure information from these interfaces to the cloud and can also communicate with the required database for reporting to the user's request.

4.3.2 Predictive Framework for User Activity

Presented predictive user activity framework keeps both the users and healthcare personnel updated [26]. Here, user of the system has been considered as a smart user and performs health-related activities in sustainable health centres. These sustainable health centres have equipment fitted with sensors which are sufficient to capture the basic parameters related to the users' health activities, such as average heart rate, total calories burned, total distance and average speed. This framework captures the information required once the user completes the exercise. Regular activities in these health centres are believed to be able to keep a user fit rather than on the heavy dependence on medicines. Healthcare personnel also suggest the same, and encourage regular physical activity to keep healthy for a longer time and avoid an overdose of the prescribed medicines. The proposed activity framework monitors the user's activity on a regular basis and updates the captured information to the required cloud. In case the user does not perform an activity for a specific time period then this information will also be updated in the cloud database and an alert will be sent to the respective healthcare personnel, who can further communicate with the user regarding understanding the status of his health.

Figure 4.6 represents the user activity framework from the beginning and until the end of the physical activity in a sustainable health center. As the biometric identification and authentication are completed for the user, a secure session gets established with the local database server to monitor the user's activity on that equipment. Here, it is considered that the equipment has embedded sensors which can monitor and transfer the details of the basic parameters like heart rate, total calories burned, total distance and average speed to the connected local database servers. As soon as the physical activity session is over, the equipment stops and the respective values of the basic parameters are stored in the local database server of the sustainable health center. In case the user terminates the session in the middle of the physical activity then that session will be marked INCOMPLETE and the

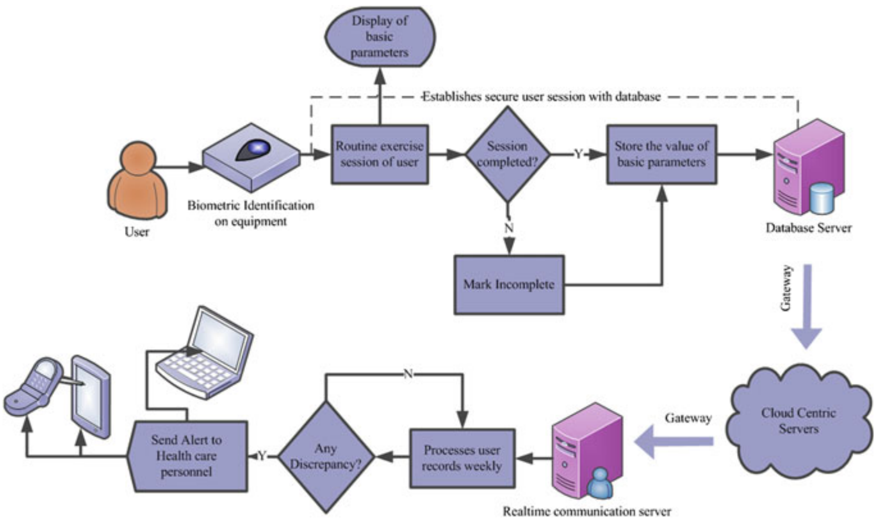


Fig. 4.6 Predictive user activity framework

respective values of the basic parameters are stored in the database. In the next step of this framework, the information stored at the local level is transferred via the gateway to the various cloud servers. These cloud servers keep the information up-to-date and secure. Later on, this stored information is picked up by the real-time communication servers located geographically with the different healthcare personnel. These real-time communication servers process the record thus obtained and relate them to the user on a weekly basis to produce the reports accordingly. If the user regularly terminates the physical activity sessions, before the prescribed activity time for particular equipment or is absent from the sustainable health center then an ALERT message is sent to the user's healthcare personnel either in the form text message or an Email alert.

4.4 Cloud-Based Predictive Computing Design

The proposed cloud-centric architecture reduces the overall complexity of the implementation of the system [26]. It implements various security measures at each step of the communication of the information. As shown in Fig. 4.7, the initial level collects and stores the information for each user from the sustainable health centres into their database server at the local level. The information collected represents the daily values of the basic parameters the specific user has worked out. To communicate this information thus gathered over the cloud the XML web services have

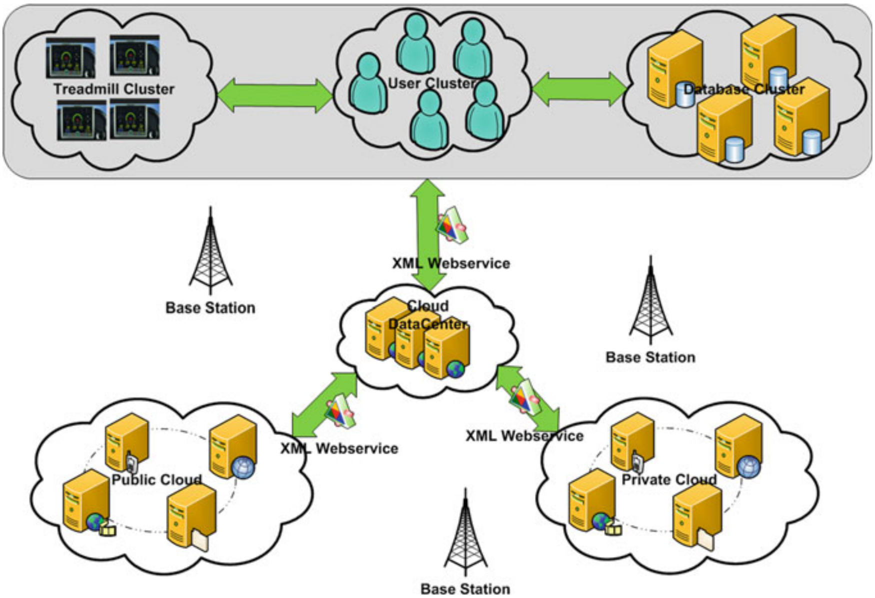


Fig. 4.7 Cloud-based predictive computing design

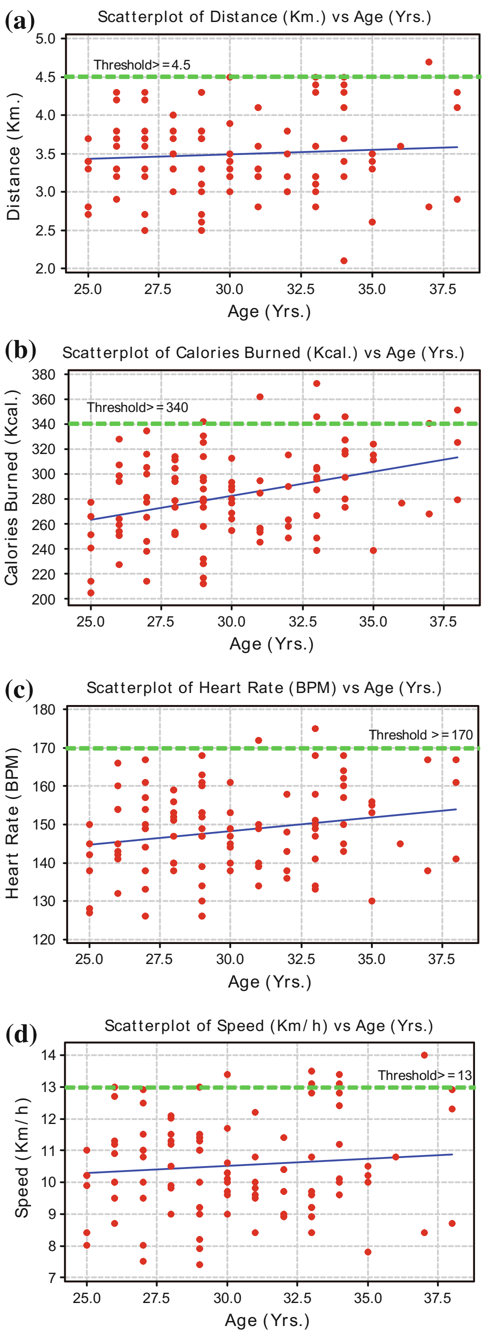
been used as these are considered secure and faster. From the initial level, the information is collected from the various database clusters distributed to the cloud-centric data center. These data centres also ensure the security of the stored information and further disseminate the information to the public and private clouds.

Both private and public clouds are equipped with a mobile information server, content management server, file server and streaming media servers. These servers continuously exchange information whenever required with their respective clouds. While implementing this architecture, different algorithms are used with different types of clouds to maintain the integrity, consistency and security of the user's information.

4.4.1 Predictive Analysis of Physical Activities

The proposed framework presents the ease of interface to both the healthcare personnel and users. While performing a physical activity in a sustainable health centre, it represents no interface to the user except for identification, authentication and establishing the session with the local database server which is responsible for storing the values of the basic parameters as the user completes the session. We have performed the analysis on average data collected in real time from five different nodes up-to duration of 30 days for time interval 20 min every day. To vary the considered data for experimental purpose requires more nodes and time so that the data could be collected in real time. However, this will not affect the overall performance of proposed architecture as from collected data our main objective is to test the alert mechanism of proposed user activity framework. Figure 4.8 represents the values of the basic parameters stored after 20 min of each physical activity session by the users. It shows the various scatter plots for the distance, calories burned, heart rate and speed with respect to the age of the users. Healthcare personnel can thus define the daily maximum threshold value of these parameters for their users individually and further predictive analysis can be performed accordingly. Here, Fig. 4.8a represents the threshold value for distance ≥ 4.5 km, Fig. 4.8b represents the threshold value for the calories burned ≥ 340, Fig. 4.8c represents the threshold value for the heart rate ≥ 170 bpm, and Fig. 4.8d represents the threshold value for speed ≥ 13 km/h. While performing prediction analysis, the defined threshold values of these basic parameters are checked and if any of value exceeds the limit then an alert is sent to respective healthcare personnel to initiate the necessary action. Also, if a user misses the physical activity session for a whole day or terminates the session in between, then also a message 'INCOMPLETE/ABSENT' gets stored into the database.

Fig. 4.8 Scatter analysis of users on treadmill **a** distance (km) versus age (years), **b** calories burned (Kcal) versus age (years), **c** heart rate (bpm) versus age (years), **d** speed (km) versus age (years)



4.4.2 *Predictive Efficiency of Framework*

The efficiency of the proposed framework is evaluated using the total communication time, and end-to-end delay.

– *Total communication time* represents the total time taken for the storage of information from the local database server to the cloud data centre and further to the public or private cloud. This time can exceed if there is any alert sent from the public or private cloud to the healthcare personnel. Here, Eqs. 4.1 and 4.2 show the computation of the total transmission time where n represents the number of clusters, t is the time, and w the total offloading iterations and x total number of alerts.

$$T_{\mathrm{TIME}} = \sum_{i=1}^{n} (t(w) + t(x)) \tag{4.1}$$

If there is no alert then the value of $t(x) = 0$ and Eq. 4.1 will become:

$$T_{\mathrm{TIME}} = \sum_{i=1}^{n} (t(w)) \tag{4.2}$$

– *End-to-end delay* represents the information delay time between the nodes. This can be computed by subtracting the minimum time of communication from the total time of communication. Its minimum value shows the early arrival of information at the destination node (Eqs. 4.3 and 4.4).

$$T_{\mathrm{delay}} = T_{\mathrm{TIME}} - T_{\mathrm{minimum}} \tag{4.3}$$

$$T_{\mathrm{minimum}} = f(T_{\mathrm{TIME}}, \mathrm{minimum}) \tag{4.4}$$

Figure 4.9 represents the total transmission time for both the public cloud and private cloud. Here, the value of T_{TIME} reaches up to 12 s for the public cloud and

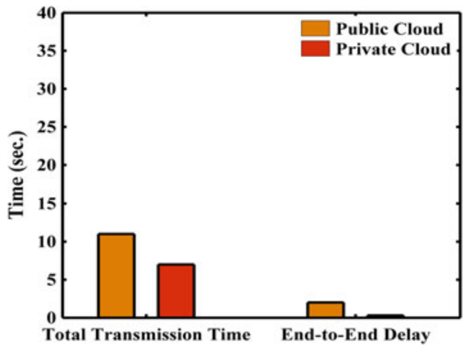


Fig. 4.9 Efficiency of cloud-centric framework

7 s in case of the private cloud. The higher value of T_{TIME} for the public cloud shows that more users are connected with it, as the services are not payable to this cloud.

4.5 Summary

In this chapter, we have presented an integrated view of IoT and cloud computing and proposed a predictive healthcare framework for monitoring of physical activity of user. The proposed framework simplifies several of these issues and stops the proliferation of information. This framework can be used by user of any age group. The proposed framework, has been evaluated on the basis of predictive analysis of physical activities, and its efficiency. There was also an understanding that to minimize the overall cost there should be a minimum time delay between the advice time and issue reported time. This can be observed from the analysis performed for the end-to-end delay for the proposed framework. Predictive analysis of the physical activities represents the results collected in real time using the sensors for the various users on the treadmill for a 20 min time duration. These results also present the common threshold value for all the users, although the healthcare personnel can define it separately for the individual users. Overall, the architecture presented and discussed is more robust and secure in nature, although a lot of work could still be done in the future for its improvement. The issue of load balancing and information distribution throughout the cloud servers can be considered, and proposed framework can be extended to include more health parameters and activities.

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