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PTFIC - Patient Health Tracking through Fog Enabled Internet of Things Network Using Optimized Classifier

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Abstract: The network creates a lot of data, which may be saved and processed by a cloud system, though Internet of Things (IoT) technology reinforced with a fog-enabled cloud computing system to monitor remotely. The data transit between the user and the cloud is processed to generate the communication, internet service, and cloud storage function. To facilitate remote patient monitoring, we suggested PTFIC - patient health tracking over a fog-enabled Internet of Things network utilising an optimised confidence classifier and a fog layer at the gateway. The fog layer oversees patient data validation and transmission by utilising the classifier to analyse significant events by determining the health state.

Keywords: *IoT; Fog; Cloud Network; Confidence Classifier; Patient Monitoring.*

1. Introduction

The transfer of on-demand services in healthcare has been revolutionised by cloud and fog computing, yet cloud computing is not a viable substitute since it has time delays for systems that need real-time answers. Fog computing has numerous recompenses, including decreased delay, amplified bandwidth, dependability, operation that uses less energy, safety, and stretchy communication. Fog computing's key benefit is intensifying scalability and storage volume while enhancing the competence of data collection, processing, and analysis. Fog computing is the use of several, physically separated devices that are often connected to a network to share computer resources and provide scalability, flexibility, and processing power. The fog method expedites time, virtual supervision, and illness assessment. The connected components can be linked via network access points, gateways, and routers, as well as protocols, to enhance its operations. Because of its location awareness, heterogeneity, movement provision, interoperability, scalability and ongoing interactive services, fog may be an outstanding choice for IoT-based healthcare nursing system. The fog-based remote patient monitoring system comprises a decision-making layer DML, a data collecting layer DC, an information withdrawal layer IWL, an event organization layer EOL, and a cloud storage layer CL. Each layer efficiently serves the layers underneath it by performing the tasks that are assigned to it

Fog computing also focuses on fluctuations in temperature, moisture, noise level, pollution, and smoke level through sensors, wearables, and gadgets as shown in Figure.1. To gather this kind of information, several sensors are placed around the area. Patients who spend a plenty of time in bed may have various alterations in their blood pressure, breath count, heartbeat, pulse rate, and sugar level, which may explain data inconsistencies. The network's goal is to provide essential validation services closer to the point of demand, at the edge of the network, so that users may organise resources in rational positions to increase efficacy. Less distance must be covered by the network for user data.

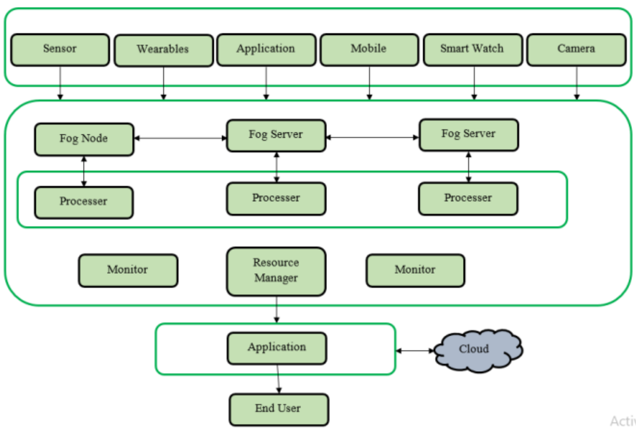

Fig.1 Fog Operational Method

The device layer, the fog layer, and the cloud layer are all components of a fog-based IoT system. Only when an undesirable event occurs the cloud layer alerted after the fog layer has first reviewed the information gathered from numerous components. IoT-based applications now outweigh fog-based applications, although the number of fog-based applications is growing. Instead of transmitting a massive data to the cloud, fog layer examines time-delicate data at the network edge. Each fog node in the fog layer interacts with other nodes in its computing environment to

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start a process. Most IoT applications may run more professionally with the help of fog computing, which will increase the number of smart sceneries.

The major focus of the proposed PTFIC approach was the remote patient monitoring system with fog and cloud help from the IoT network. The sternness of the data is determined by the fog layer, which then transmits it to the cloud for further processing. In this work, data categorization done at the fog layer, then alert-based decision-making in various situations taken at the cloud layer, and then information transfer to the medical centre MID, ambulance AID and family carers FCID after optimised validations are performed in PTFIC as shown in Table.1.

Table.1 Cloud Layer Decision Options

Medical Centre	Ambulance	Carers

The document is organised as follows: Section.2 of the publication detailed prior validations and pertinent methodology. Section.3 explained the PTFIC – patient health tracking through fog enabled internet of things network using optimized classifier and section.4 discussed the results and validations of the work and the end section concludes the design and future work.

2. Related Works

Fog computing is a concept that aims to address the problem of how to properly execute all information processing brought about by smart devices in the IoT. Its goal is to eliminate the necessity for sending created data to the cloud by enabling processing of that data to take place nearby, at the network boundary, or directly at the device [3]. The term "cloud computing" refers to the many services and applications that are delivered over the internet cloud, and it is believed that no specific apps are needed on the devices in order to access these services and applications. Cloud computing provides resources that assist with data management, processing, and storage. In order to achieve consistency and economies of scale, cloud computing is dependent on resource pooling [15]. Cloud-based solutions enable the collection of data from several sites and devices, output is delivered once more to the target device, resulting in a response delay, and huge data requires high bandwidth. Another key worry is user privacy and data security. These are the justifications behind people's reluctance to use the cloud [1]. The main factors driving this technology's exponential growth are cloud services virtualization, rapid elasticity, global network access, and superior performance. With typical "off-the-shelf" software packages, an application is often installed on the company's main server before moving on to each office PC. Both small and large businesses use cloud computing technology to store information in the cloud and provide access to it from anywhere via an internet connection [16]. There are a lot of opportunities in the healthcare industry thanks to the IoT's rapid expansion and development. The dependability of the healthcare system and the effectiveness of daily life are significantly impacted by fitness trackers, wireless technologies, and body sensors. The applications of wearable devices are increasing which measure physiological factors, enhance adherence to exercise in various populations from athletes to patients, and promote health [4]. The result has been the development of fog technology. IoT devices, data sources, and the cloud are all connected through a distributed architecture called cloud computing. The implementation of the cloud close to the machinery that produces and processes the data is possible with the help of fog computing technologies. Fog nodes are the devices utilised in this solution, and they may be deployed anywhere thanks to network connections [2]. Fog computing implementation On the RAN, several people are investigating how to use personally owned WiFi routers as fog computing apparatuses, either to carry out calculations or as a means of facilitating service discovery. The fact that these devices are so common and frequently underused is what drives this. Free WiFi access is already promoted by a number of programmes. An open computer ecosystem, in our opinion, [6]. The user has limitless access to cloud computing capabilities whenever needed. Users often prefer a middleman provider for the internet service in cloud computing rather than building up their own physical infrastructure. The on-demand, pay-as-you-go distribution of networking, computing power, and IT resources through the internet is known as cloud computing. According to this, the goal of cloud computing is to store and access data and software over the internet rather than on the computer's hard drive [9]. Big data are created quickly, making it challenging to store, analyse, or manage them using conventional software. Big data technologies are instruments that can store valuable data in a variety of forms. A variety of analytical frameworks have been made available to help users analyse complicated structured and unstructured data in order to satisfy user needs and analyse and store complex data [13]. The widely supported relationship between IoT and cloud computing is enabling practical and useful application by other market personnel on the planet to provide benefits in the competitive sophisticated globe. With the number of heterogeneous devices linked to the IoT and the data age growing, it will be extremely difficult for the open IoT to use power and transmission capacity for projects efficiently [11]. With the aid of certain programmes and the internet, cloud computing is a paradigm that offers its clients affordable processing, storage, and a variety of other services upon request. Pay-as-you-go is the foundation of this approach. According to the resources and data you utilised, which are automatically measured, the price will vary [5]. The cloud computing service model involves a service provider providing enormous pools of high-performance computer resources and high-capacity storage devices, which are subsequently shared as required among end users. A fast network is necessary for the cloud service paradigm to link the end user to the infrastructure of the service provider. Cloud computing has many different meanings, and the IT sector is still debating potential future services. The term "green cloud computing" refers to the use of computers and related resources in a sustainable way [14]. Cloud computing is the term for the on-demand provision of computer system resources, primarily data storage and processing power, without direct active supervision by the user. Large clouds usually distribute their functions across a number of locations, each of which is a data centre. The "pay as you go" approach that cloud computing often employs can assist decrease capital expenditures but may also cause unforeseen running fees for consumers. Coherence in cloud computing requires resource sharing [12]. Cloud services enable organisations to employ the most advanced technology, which gives them a competitive edge. Businesses and organisations have also come to realise that utilising the same services from a single cloud computing platform may help them cut costs and enhance coordination with their suppliers [8]. With telecoms companies diversifying their offers and expanding their income streams by using their current infrastructure and providing cloud computing services, cloud-service suppliers are emerging as the superheroes of our time. The prediction is that even after this pandemic, there will be an addition in the number of organizations relying on these vendors to effectively conduct business. Cloud solutions and the reliance on regional cloud service providers for connection would make organisations more comfortable and connected [10]. Hackers utilise a variety of strategies and tactics to gain unauthorised access to cloud services. In addition, these criminals disrupt cloud services in order to achieve their intended goals. There is a chance that hackers would deceive cloud computing services by passing off their unauthorised access to data as a legitimate entry, giving them power over who can access the data that is kept in the cloud [7].

3. PTFIC Design and Implementation

Network Model

The network was developed with a variety of internet-enabled components, like as sensors, base station, Fog gateway G_W, servers, virtual machines, storage and datacentres to establish the network capable of recording and processing a wide range of patient data as given below in Table.2.

Table.2 Patient Data

Patient ID
Disease
Medical Report
Doctor ID
Sensor ID
Gateway, Access point, Internet Service Provider
Ambulance, Family Member
Fog Node

A decision will be made at the cloud layer in a communication system where the fog layer may retrieve the patient's medical history from the cloud layer once data has been validated and handed over to it for classification. The mining layer is utilised to extract data from the fog and transform the diverse data into a format that is widely used.

The foremost goal of the PTFIC system is to remotely observe the health of patients by using the fog-centric internet of things acquaintances. The fog layer is made up of fog nodes that are positioned near the network's edge as shown in Figure. 2..

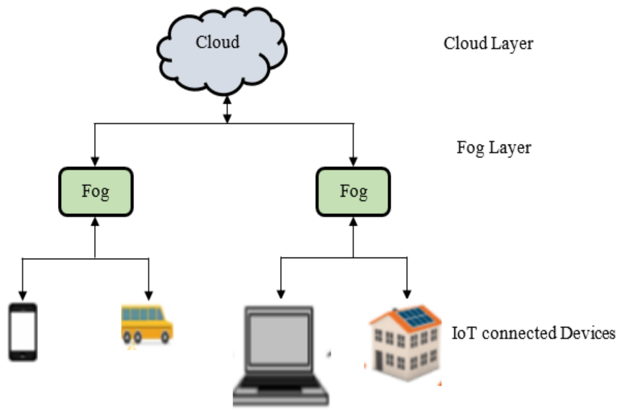


Figure.2 Fog Enabled Cloud Network

The data acquisition layer collects data from IoT, it interfaces the external data about diverse occurrences in the patient's health from one-hop or remotely connected to the patient.

Cloud Layer Activities

To obtain the data, the patient's body sensor network and wireless communication system are put at various areas across the patient's residing area. These devices can use wireless sensing originalities to transmit and observe data in factual time. Each sensor node has biosensors and other medical sensors, and the coordinator fog gathers textual, realistic, and numerical data from a person's biological topographies. As a consequence, fog nodes transform these findings into the right format before transmitting them to the cloud layer for further check-ups. Fog nodes may also synchronise data acquired from numerous devices simultaneously.

The patient must register their information, including private data and available medical history. Following registration, the cloud server assigns a unique identification number to the patient and sends attribute sets pertaining to the patient's medical history to the appropriate fog node.

Fog Layer Activities

When an anomalous event happens while being observed from patient, the cloud layer receives the most recent time data from the fog layer. The pre-and post-few-minute sensing data will be delivered to the cloud layer for further examination, together with a number of other vital information by fog. Normally, people with regular health difficulties have subordinate levels of invulnerability in their bodies, making them more prone to illnesses than healthy individuals, that data is observing by sensors and processed by fog and cloud layers.

The secure socket layer is supports to protect and secure the channel between the various system mechanisms; the recent application set-up is event-driven. Consequently, the essential real-time data is upheld at the fog nodes for emergency access. The fog layer will handle and analyse data by connecting with other fog nodes and fog data services as discussed below. Here, A_P is access point ID.

Sense patient data and update sensor ID, A_P ID,

Find Fog G_W and send data to Fog

Classify and forward data to Cloud Layer

Cloud takes decision

An enormous volume of data is congregated in the network to categorise the patient condition as either regular or irregular. The recommended systems provide priority-based transmission that is based on the patient's health. A critical event detects when the collected data deviates from the expected range. High or low heartbeat, peak temperatures, pulse rate variations, glucose level and peak blood pressure are examples of critical occurrences.

Using the confidence classifier, the patient data is categorised as regular or irregular as follows.

- Govern the critical data to be resolved.
- Then, describe the connections between all devices.
- Finally, define the probability guidelines that normalize the relations.

The conditional probability idea underpins the confidence classifier's C_C operation. Based on the data values D_V, each event would be classified as either regular R_R or irregular I_R if $P\left(\frac{R_R}{D_V}\right) > P\left(\frac{I_C}{D_V}\right)$, where $P\left(\frac{I_C}{D_V}\right)$ reflects the probability of the event being classified as I_R for the health D_V. Still, $P\left(\frac{R_R}{D_V}\right)$, is defined as the probability of an event R_R computed below:

$$P\left(\frac{I_C}{D_V}\right) = P\left(\frac{\frac{D_V}{R_R}\, P(R_R)}{P(D_V)}\right)$$

Here, $P\left(\frac{I_C}{D_V}\right)$ represents the likelihood that of D_V will occur when any occurrence is computed using the R_R state. $P(R_R)$ is the likelihood that an event will fall within the regular indication based on health indicators, and $P(D_V)$is the likelihood that D_V will be present.

The classifier assumes that all qualities are autonomous when dealing with healthiness features in the context of patient care. The key set of potentials described below in Table.1 as patient data is included in a twin-stage confidence computation that is used to solve this problem. Here, P_{HR} is patient record, A_R is atmosphere record and C_R is character record. The health H_C catalogue calculated following that average A_{VG} and variance V are calculated to find the final catalogue value as computed below.

Table.3 Patient Data

Region Heat RH	Pollution	Noise NS
Moisture MS	Blood Pressure BP	Heart Issues HI
Fever FV	Glucose-GL	Breath Count
Respiratory Level RP	ECG	EEG
Diabetes DT	Pulse Variation	prolonged disease

$$M_S = \frac{M_S - M_{SL}}{M_{SU} - M_{SL}}$$

$$N_S = \frac{N_S - N_{SL}}{N_{SU} - N_{SL}}$$

$$R_H = \frac{R_H - R_{HL}}{R_{HU} - R_{HL}}$$

$$H_{C1} = (ECG + ECGL + ECGU)$$

$$H_{C2} = (EEG + EEGL + EEGU)$$

$$H_{C3} = (R_P + R_{PL} + R_{PU})$$

$$H_{C4} = (B_P + B_{PL} + B_{PU})$$

$$H_{C5} = (G_L + G_{LL} + G_{LU})$$

$$H_{C6} = (F_V + F_{VL} + F_{VU})$$

$$A_{VG} = \frac{H_{C1}}{3}, \frac{H_{C2}}{3}, \frac{H_{C3}}{3}, \frac{H_{C4}}{3}, \frac{H_{C5}}{3}, \frac{H_{C6}}{3}$$

$$V1 = \frac{(A_{VG} - ECG)^2 + (A_{VG} - \text{ECGL})^2 + (A_{VG} - \text{ECGU})^2}{3}$$

$$V2 = \frac{(A_{VG} - EEG)^2 + (A_{VG} - \text{EEGL})^2 + (A_{VG} - \text{EEGU})^2}{3}$$

$$V3 = \frac{(A_{VG} - ECG)^2 + (A_{VG} - R_{PL})^2 + (A_{VG} - R_{PU})^2}{3}$$

$$V4 = \frac{(A_{VG} - ECG)^2 + (A_{VG} - B_{PL})^2 + (A_{VG} - B_{PU})^2}{3}$$

$$V5 = \frac{(A_{VG} - ECG)^2 + (A_{VG} - G_{LL})^2 + (A_{VG} - G_{LL})^2}{3}$$

$$V6 = \frac{(A_{VG} - ECG)^2 + (A_{VG} - F_{VL})^2 + (A_{VG} - F_{VU})^2}{3}$$

$$H_{Ci1} = \sqrt{V1}, H_{Ci2} = \sqrt{V2}, H_{Ci3} = \sqrt{V3}, H_{Ci4} = \sqrt{V4}, H_{Ci5} = \sqrt{V5}, H_{Ci6} = \sqrt{V6}$$

$$P_{HR} = H_{Ci1} + H_{Ci3} + H_{Ci4} + H_{Ci5}$$

$$A_R = M_S + N_S + R_H$$

$$C_R = H_{Ci2} + H_{Ci6}$$

$$P_{HRHC} = H_{CPHR} P_{HR}$$

$$A_{RHC} = A_R H_{Ci} H_{CCR}$$

$$P_{HRHC} = A_R C_R$$

$$H_C = P_{HR} A_R C_R$$

In the context of patient monitoring, environmental circumstances and the patient's medical history are crucial in forecasting the likelihood of an occurrence. The following metrics and boundaries determine the disease probability boundary difference D_{iff} .

Lower L_B and Upper U_B bound

Determine Health catalog H_C

Sensed Data input Layer is current Log

Update ECG, EEG, R_P, F_V, B_P, G_L L_B and U_B

Hidden Layer receives input Layer ECG, EEG, R_P, F_V, B_P, G_L L_B and U_B

//input layer I_L parameters processed and transferred to hidden layer H_L

$H_L \rightarrow D_{iffLB} = I_L \rightarrow ECG - ECGL,\ EEG - EEGL\ , R_P - R_{PL}, B_P - B_{PL}\ , G_L - G_{LL},\ F_V - F_{VL}$

$H_L \rightarrow D_{iffUB} = I_L \rightarrow EEG - EEGU\ , EEG - EEGU, R_P - R_{PU}, B_P - B_{PU}, G_L - G_{LU}, F_V - F_{VU}$

$If\ H_L \rightarrow D_{iffLB} \leq H_C$

$H_L\, Prob \pm 0.5$

$If\ H_L \rightarrow D_{iffUB} \leq H_C$

$H_L\, Prob \pm 0.5$

The findings of the patient's medical history contain complicated compound qualities like heart disease, blood pressure, and other observations. The degree of influence score D_S is used in the second stage of the classifier to categorise patient state determination P_{SD} through sensed data S_D as discussed Below:

$D_S = P_{SD}$

$if\ (D_S > 0.4)$

$P_S \rightarrow 1 \rightarrow I_R$

If Fog G_W is true update state is positive

Else update $P_S \rightarrow 0 \rightarrow R_R$

The probability value that might classify an occurrence as falling inside or outside of the regular range is referred to as the degree of effect. This stage incorporates the output from the first stage as well as certain significant unique features.

PATIENT STATE DETERMINATION

Update patient state → If $D_S > 0.4$ declare patient state is irregular else regular

If sensed data → ECG ≤ 60 or sensed data → ECG ≥ 100

sensed data → EEG ≤ 17 or sensed data → EEG ≥ 27

sensed data → R_P ≤ 55 or sensed data → R_P ≥ 80

sensed data → B_P ≤ 85 or sensed data→ B_P ≥ 120

sensed data → G_L ≤ 110 or sensed data→ G_L ≥ 240

Declare R_R else I_R and Update disease range:

P_{SD} Computation→ BP range B_{PR}, RP range R_{PR}, ECG range ECG_R, EEG_R range, G_L range G_{LR}

If sensed data → ECG ≤ 60 or sensed data → ECG ≥ 100

ECG range = 0.75 else ECG range = 0.25

sensed data → EEG ≤ 17 sensed data → EEG ≥ 27

EEG range = 0.75 else EEG range = 0.25

sensed data → R_P ≤ 55 or sensed data → R_P ≥ 80

R_P range = 0.75 else R_P range = 0.25

sensed data → B_P ≤ 85 or sensed data→ B_P ≥ 120

B_P range = 0.7 else B_P range = 0.25

sensed data → G_L ≤ 110 or sensed data→ G_L ≥ 240

$G_L$range = 0.75 else G_L range = 0.25

$$D_S = \frac{(B_{PR} + R_{PR} + G_{LR} + EEG_R + ECG_R)}{5}$$

The sensors on the patient's body collect the data values relating to patient health. Each fog node receives past data on patient health from fog data services, which is situated closer to the cloud server. For unbalanced patients, the data are recorded using wearable sensors. There are billions of data points, which prevents analysis at the fog layer., so it sends ECG and EEG data to cloud layer for further analysis if the patient D_S rises beyond a certain threshold. Data attribute and a time-series pattern can be defined as a set of values over a period. If the value is recognised for one or more distinct time it may be seen as a vector.

A fitness index is a probabilistic value generated from an observational attribute. The process of simultaneously measuring parameter variations results in the creation of the patient index, which indicates the health status of the patient. Higher scores denote unsafe situations. The index is crucial since it alerts readers to any urgent medical needs. The index value is evaluated using the average weighted provisional probability approach. By calculating the results of the catalogue value, the patient's health state and the seriousness of each changes detected.

if(P_S== 1)

Verify cloud guard Time CGT

Create session and accept cloud data with G_W ID

Update sensed data

Δ = nano Time -CGT

if(Δ > 0) stop action and monitor IWL

H_C = Determine using C_C

if(H_C > α)

if F_L data is correct

in cloud layer update Fog user device and data Count

if(F_L sensor ID and F_L user D_T is correct)

User can access data from cloud

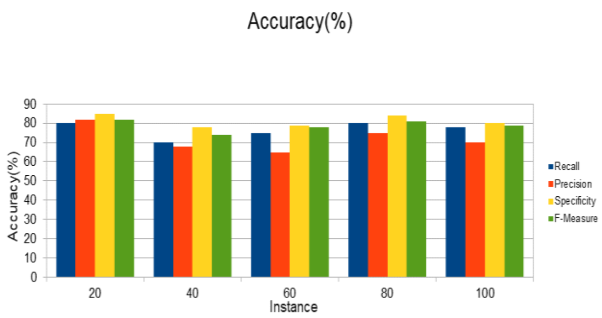
MID, AID and FCID are available to access data

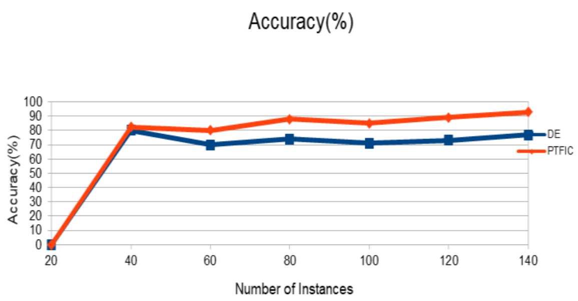
The input provides the number of values for each health condition attribute and each attribute threshold value is prefixed in the fog-assisted network, which saves the final monitored data in a private cloud for future use and determining the P_S. The patient's present status was then made clear by the output. Determine the current context and P_S using these data using the state range. After that, identify the P_S using the H_C and the incident's time stamp, and inform via the cloud layer if it is irregular. During notification, provide the H_C and notify the enrolled FCID to alert them to the patient's condition as discussed above.

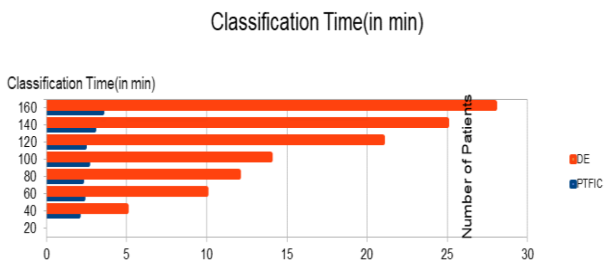
The D_{MI} procedure based on fog clouds is possible to lessen the critical situation depending on the criteria. The threshold value for each patient is different and is determined depending on the patient's past medical experience. The acquired data may be kept and analysed at fog and cloud layers using a record. The cloud layer is essential for gathering and merging patient data summaries from various fog nodes and provides information to the layer that helps it locate medical facilities and other emergency services, such as ambulances. The data may be used by medical facilities and the general population in research projects and surveys to develop new vaccinations to treat certain diseases.

The IoT connection established with fog assistance, the network monitored patient, environmental, and category of health data, the computations categorize the report of health as an output and the monitoring at every time occurrences. Each category's probability set, which assigns H_C including patient type, criticalness, and other factors, has been developed.

4. Results and Discussions







Instance	Recall	Precision	Specificity	F-measure
20	80	82	85	82
40	70	68	78	74
60	75	65	79	78
80	80	75	84	81
100	78	70	80	79

	At Beginning	At Middle	END
Classified Accurately Instances	5704(91%) 5766(92%)	5515(88%)	5419(86.4%)
Improper Classifications	564(9%) 502(9%)	753(12%)	849(13.6%)
Mean Square Error	0.237 0.204	0.312	0.3210
Total Number of Instances	6,268 6,268	6,268	6,268

Accuracy is defined as the percentage of correctly identified data ranging from 0 to 1. To calculate the proportion, just count the number of correctly classified data and divide it by the total data size and the outcome achieved as 95% in PTFIC than differential evaluation. Also, the classification time is reduced in proposed method. Also, the health record classification time is reduced because of the computation methodology using confidence classifier. Recall is used to assess performance by counting the number of accurate true positives out of all positive values. Precision is a valuable measure of prediction success when the data is highly skewed. The specificity measures ability is to evade false positives.

5. Conclusion

The Internet of Things and fog computing have benefited human lives through regular monitoring of health conditions, predominantly distant patient health status monitoring. The network accelerates therapy by gathering data through sensors; it is a significant aspect of the medicinal profession; the innovation sector of network is growing with multiple discoveries such as IoT sensors, diverse devices, fog, and cloud computing. The network uses a health catalogue report and the confidence classifier to forecast the patient's state, and reports on check-ups, actions, and medications. Future work will try to advance by establishing a minimum delay secure encryption system in a fog-enabled cloud network. F-metric combines accuracy and recall into a single metric that collects both features.

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