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# Remote Patient Monitoring in FOG Computing Environment using Bayesian Belief Network Classifier Algorithm

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**Abstract: The comfort and ease of human lives are significantly improved by the Internet of Things (IoT) devices' integration of medical signal processing capabilities with cutting-edge sensors. Providing healthcare services to every patient, especially the elderly person those are living in the remote areas and suffering chronic diseases need to monitor in real-time. Remote patient monitoring systems are designed to obtain a number of physiological data from the patients. Most common data are Electrocardiogram (ECG), Electroencephalogram (EEG), heart beats and respiration rate, oxygen volume in blood or pulse oximetry, signals from the nervous system, blood pressure, body/skin temperature and blood glucose level. In this research work, a FOG computing architecture is suggested for the real-time deployment of a remote patient monitoring system. Reducing latency and network consumption is the main driver behind the suggested approach's use of the FOG paradigm. Due to the large amount of data involved in healthcare and the enormous value that accurate predictions hold, the integration of machine learning (ML) algorithms is imperative. The use of Bayesian Belief Network (BBN) classifier algorithms in the healthcare applications that are covered in this work has demonstrated experimental evidence of accuracy and usefulness.**

***Keywords:-*** Internet of Things (IoT), FOG, Remote Patient Monitoring, ECG, Machine Learning, Bayesian Belief Network.

## I. INTRODUCTION

The Internet is being used as a cutting-edge tool that not only aids in streamlining the healthcare industry as a whole but also improves patient care [1]. The basic idea of Industry 4.0 is driven by various emerging technologies such as big data analytics, machine learning, blockchain, etc. This research endeavor is all about the transformation of healthcare to the current Healthcare 4.0 version that revolves around the concepts of Industry 4.0. Fog computing not only brings the cloud computing paradigm to the edge of the network but also addresses unsupported or unfit fundamentals of cloud paradigm. The problems like edge location, high latency, location awareness, reliability, and moving data to the best location for processing are resolved by fog computing [1] [2]. Fog can be described as placing light-weight cloud like facility at the proximity of the mobile users. Indispensably, Fog is deployed at location sites, by providing engaged localization services desirable to mobile users. Fog based IoT system consists of three layers namely device layer, fog layer, and cloud layer. The fog layer first analyses the health data collected from various IoT and medical sensors only notifies the cloud layer in case of an adverse event happening situation. However, the number of Fog-based applications is increasing. As expected, in 3-5years, the number of Fog-based applications might become more than the IoT itself. Fog layer analyses the real time- sensitive data at the network edge instead of sending a vast amount of data to the cloud. In addition, at fog layer, each fog node communicates with other nodes in its computing environment to initiate an action. Because of the proximity to the end-users compared to the cloud data-centers, fog layer has the potential to offer services like latency reduction for Quality of Service (QOS) and stream mining resulting in superior-user experience. Furthermore, many applications are recently developed using IoT technology which requires real-time data analysis and decision making. Cloud computing setup cannot fulfill real-time requirements in many applications. In addition, IoT applications such as Smart Grid, Smart Homes, and ICU are latency sensitive and therefore require immediate analysis of data and decision making as a conduction of action [3]. So, an intermediate layer has been proposed termed as fog layer which can perform real-time analysis of data generated by IoT device with minimum-latency. FOG computing can increase the effectiveness of most of the IOT applications which in turn can increase the number of smart environments. In our approach, FOG assisted-IOT enabled remote patient monitoring system is developed by considering various event instances.

## II. RELATED WORK

This section provides a brief definition of the cutting-edge healthcare for remote patient monitoring systems relevant to cloud- and fog-based architectures. In [4], the authors proposed a cloud-based remote patient monitoring architecture in which the cloud works as a bridge between IoT devices and a web application. A low-energy wearable bio-sensing mask was designed to capture sEMG and ECG signals, which were further processed to evaluate patient conditions. A web application was developed to present data for real-time remote patient monitoring. The same architecture was employed in [5] for remote monitoring of persistent vegetative state (PVS) patients through analyzing

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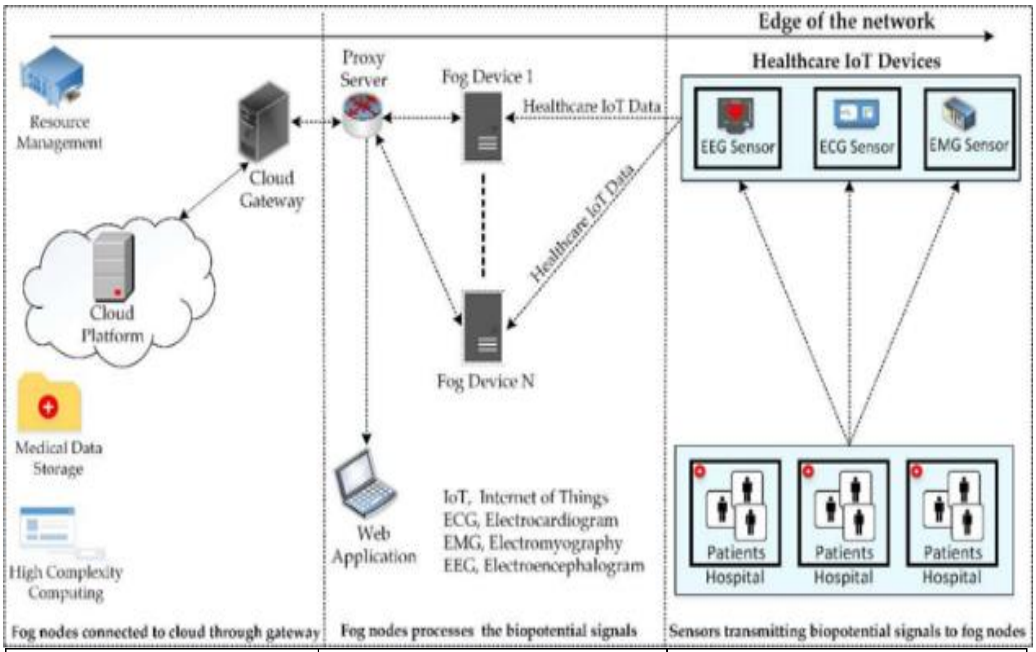
real-time signals related to facial expressions. In [6], the authors discussed different strategies for interconnecting healthcare applications and articulate the approach of implementing them in the healthcare system using mobile cloud computing. The benefits of deploying healthcare applications using cloud infrastructure are also part of this article. They designed a fall detection system for elderly people using cloud computing architecture. Tejaswini et al. [7] proposed remote patient monitoring based on cloud architecture for newborn infants to reduce the mortality rate. Infant crying is a pathological tool used as an indicator of pain in this research. Pattern classification is achieved by using support vector machine (SVM)-based neural networks. The ThingSpeak IoT platform and mobile devices are used to link clinician and nurses. Rahmani et al. [8] explained the importance of locating gateway nodes near to the edge in the architecture to over advanced-level services. To cope with the challenges involved in the implementation of ubiquitous healthcare systems, the authors proposed a fog-based architecture. To evaluate the performance of the proposed fog-based architecture, a prototype of an early warning health monitoring system was developed. The issues involved in the implementation of healthcare applications using mobile cloud architecture are discussed by Farhani et al. [9] and the fog computing paradigm was proposed to deal with these issues and to facilitate efficient network utilization in such applications. Negash et al. [10] proposed a fog-based healthcare application that consists of three tiers. The first tier of the proposed architecture consists of various sensors to detect different signals related to patients, health, the environment, and activities. The fog layer resides between the cloud and sensor layer which is responsible for the compression of received sensed data and transmitting them to the cloud for further processing. Gaigawali and Chaskar [11] structured a cloud-based healthcare system for monitoring ECG and fibrillation signals into three parts. The first part consists of bio-potential sensors to acquire ECG signals. The second part is based on the cloud server to provide resources to process and store the collected ECG data. The third part is a smartphone application to provide remote access. This approach improves the healthcare systems in the provision of remote ECG monitoring in terms of accuracy.

## III. PROPOSED FOG BASED ARCHITECTURE

The main objective of this architecture is to monitor patients requiring intensive care at remote using Fog centric IoT technology. Fog layer consists of fog nodes, located at the network edge as shown in Fig.1. Moreover, Fog features like real-time interactive services, mobility support, and scalability can serve as an optimal choice in IoT based health monitoring environment. The proposed layered approach for Fog based remote patient monitoring is composed of three layers, namely: i. IoT Device Layer (Data Acquisition), Fog Layer (Event Classification) and Cloud Layer (Information Mining, Decision Making and Cloud Storage). Each layer performs its requisite function, thereby providing efficient services for adjacent layers.




| **Cloud Layer** | **Fog Layer** | **IoT Device Layer** |
|---|---|---|
| Big data Processing<br>Data warehousing and mining<br>Business Logic | Local Network<br>Data Processing and Reduction<br>Temporary Storage<br>Remote Patient Monitoring | Wearable Sensor<br>IoT Devices<br>Real-Time Data Acquisition<br>Embedded System<br>Basic Data Processing |

Fig. 1: FOG based real-time remote patient monitoring system

*A. IoT Device Layer (Data Acquisition)*

Data Acquisition Layer performs the task of data retrieval from IoT devices about various events inside home environment related to the patient directly or indirectly. Data is retrieved ubiquitously from various wireless hardware devices embedded at different locations at home and from body sensing network of the patient. These hardware devices work on wireless sensing phenomenon and have the capability of sensing and transmitting data in real-time. Each sensor node is integrated with bio-sensors and other medical sensors. Person's physiological and environmental parameters are collected in textual, graphical and numeric form by coordinator known as Fog.

*B. Fog Layer(Event Classification)*

The patient communicates with this system by firstly registering his/her information at first instance by answering questions related to health history and personal details. After registration, a unique identification number is provided to the patient by thecloud server. To perform the classification, cloud layer provides the patient identification (PID) and attribute sets related to health history of the patients to the appropriate fog node. The transmission channel is secured with Secure Socket Layer (SSL) for providing security and protection among different entities in the system. The current application scenario works in event triggered mode.A sensitive or abnormal event indicates that the sampled data of a parameter is beyond its normal range. High temp, glucose level, blood pressure are some of the instance of the sensitive event.

*C. Cloud Layer(Data Mining, Decision Making and Cloud Storage)*

a) Data Mining:
Analyzable format since patient health is a sensitive parameter; data mining is purely based on temporal. Mining technique temporal mining is data mining technique for extracting data sets in time series pattern(tsp).

- **Algorithm1:**
Patient State Determination at Fog Layer
Input: N number of health attribute values, prefixed the threshold value for each attribute.

Output: Current state of the patient.
Step 1: Determine attributes for the current context.
Step 2: Calculate Degree of Impact (DOI).
Step 2.1: If (DOI value in Abnormal Range) Then Patient State= U n safe. Go to Step 4
Step 2.2: Else Patient State=Safe
Step 3: Return Patient State.
Step 4: Trigger the Event Occurrence=True
Step 4.1: Generate early warning signal to responder.
Step 4.2: Send vital data to the Cloud storage Repository for analysis.
Step 5: Exit

b) Decision Making:
Fog layer determines the patient health state as a safe state (SS) or unsafe state (US). SS denotes that there is no need to calculate the Health Index (HI) value of the patient. On the other hand, US denote that the patient health is unstable and an immediate course of action is required by the responder. Moreover, if the patient health state is unsafe, then Any Event Occurrence = True will be triggered for two necessary actions. Firstly, the responder is intimated with early warning signals. Secondly, real-time health data.

c) Cloud Storage:
This layer plays a vital role in receiving and aggregating health data summaries of patients from various fog nodes as shown in Fig. 1. Moreover, this layer also provides information to decision making layer related to hospital location and other services for handling an emergency situation. Summarized data can be used by many hospitals and government agencies for of different machine learning algorithms are depicted. Trained Bayesian Belief Network (BBN) classifier is tested in Weka 3.7 [12] to compute various statistical parameters. BBN classification is divided into two separate BBN components called as first and second stage, and experimental evaluation in three stages, explained as follows:

The first stage calculates the probability of environmental Exposure and patient medical history. Sampled event instanced are stored in fog node provided by Amazon. In our proposed system, different Amazon Machine Image (AMI) withed fault instance"m4. 2xlarge" is chosen to run on Cent OS 7 with a Linux 2.6.32Xen Kernel. Different classification algorithms such as neural network, k-nearest neighbor, and linear regression are also implemented to compare with our proposed BBN based method as shown in Fig.2, so that the utility of BBN in real-time monitoring environment can be experimentally justified. Complete BBN calculates event happening probability when Both BBN stages work collaboratively.

At different stages, BBN's classify event happening sensitivity with an accuracy of more than 85%. Thedetailed accuracy of each class parameter using BBN classifier is observed. Moreover, with the level of results conceived from the statistical parameter, we justify the applicability of the two-stage BBN classifier in our proposed system.

- **Algorithm 1:**
Shows the procedure for determining the state of the patient based on sampled health and environmental attributes reading at Fog node. However, the parameters which are of direct interest are used to calculate the patient health state. In addition, the threshold value of concerned health and environmental attributes are fixed for determination.

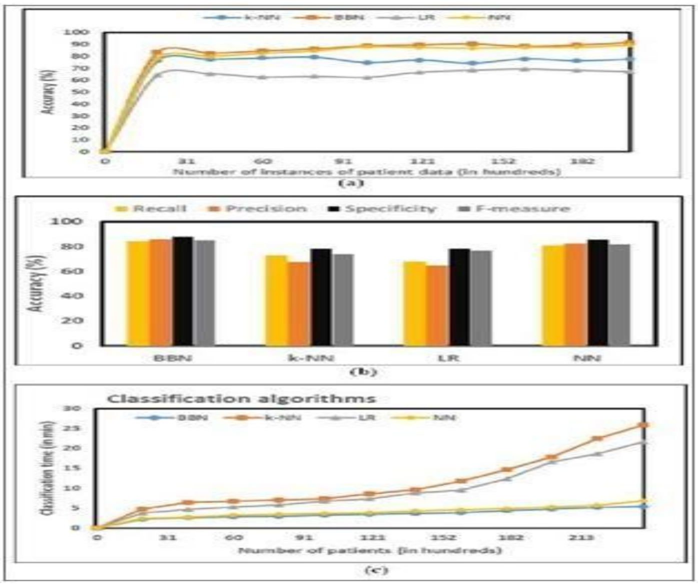



Fig. 2: (a) Performance analysis of various classification tools over theAmazon Fog.
(b) Accuracy of classification algorithms.
(c) Classification time of each algorithm

- **Algorithm 2:**
  To create data sets for remote patient monitoring system
  Input: {Patient oriented data {Patient category ∪ health data ∪ Environmental data∪ number of data sets required}
  Output: Health record data sets for each category.
  Step 1: Let "n" be the number of records required at different time instancesinitializedwith1.
  Step2.1: Assign value to health attributes as shown using probability set defined for each category.
  Step2.2: Assign value to environmental attributes using probability set defined for each patient category.
  Step2.3: Generate a new record by joining values of all attributes.
  Step 2.4: If a new record with same values of patient readings is already present in data base then discard thenew record Else Add the new record.
  Step2.5: Increment "n" by one. End if End for

readiness (8 and9)andthestudytype(Pearson$\chi 2$=5.673,p<0.014, df =1 and Phiassociation coefficient= +0.451).Also tofinda positive association between Fog assisted IoT technology level (6) and study type we computed technical feasibility (Pearson $\chi 2$ =11.464, p<0.001, df =1andPhi association coefficient = +0.451).

FromtheFig.3,onecanreachtheconclusionthatthetypes of conditions or behavior addressed by patient monitoring system that are best handled in fog assisted IoT based monitoring system are monitoring chronic pulmonary disease, health-related quality life and heart conditions of patients' with less focus on fall detection and monitoring daily activities in smart homes. Man's rho coefficient rxy=+0.439, p<0.002). In addition, we find randomized controlled trails between Fogs assisted IoT technology.

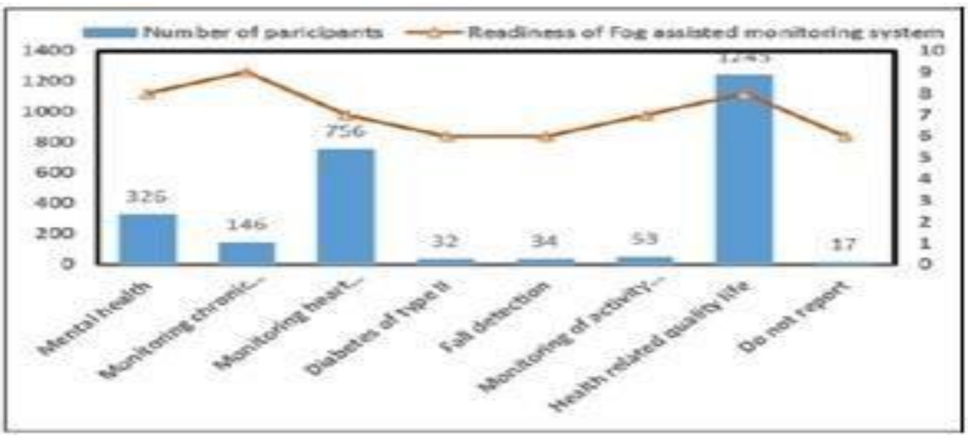



Fig. 3: Smart home monitoring conditionsvs FOG based remote patient monitoring

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## IV. CONCLUSION

The suggested architecture makes it clear that IoT-based FOG computing is more successful at providing end users with patient-sensitive information. In this paper, we introduced fog layer at a gateway for augmenting health monitoring system that requires quick processing with minimal delay. By limiting the quantity of data sent to the cloud for processing and analysis, we have used fog computing services to categorize the health status of patients as either safe or unsafe. At the fog layer, real-time event instances are watched in order to calculate event adversity. In addition, event triggering mechanism is adopted to transfer patients' health-related vital signal to cloud layer whenever patient state transitions to an unsafe state. For efficient decision-making, various events are connected in the form of temporal data granules. In treating medical emergencies, information delivery from the cloud layer to the responder is crucial. Lastly, a real-time alert generation with event severity computation further enhances the utility of the proposed system.

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