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Cloud, Fog and IOT based framework for the spread control of TB

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***Abstract*—** Tuberculosis (TB) is an infectious bacteria based disease which spreads at a high rate with person to person interaction and can even lead to death. In this paper, we have proposed a health care system for prevention and control of spreading of tuberculosis with the help of radio frequency based Internet of thing (IOT) sensor devices, fog computing, mobile phones and cloud computing. In the initial stage the cloud is used to classify the user using the decision tree on the basis of their infection, and then the alerts and monitoring is done via the fog layer. The Radio frequency based sensors devices present for sensing the proximity interactions between the users, automatically providing alert to the user about the presence of any infected individual in their proximity and this proximity data is used for the creation of Temporal Network Graphs at a local level so that the spread can be controlled easily at the local level itself thus making it easy to figure the spread patterns and mass spreader. The analysis of different metric of temporal graphs are calculated and the real time based alert generation makes the healthcare system even better.

***Keywords*—**FOG healthcare, RFID sensors, proximity contacts, temporal network graphs, Tuberculosis.

I. INTRODUCTION

The disease tuberculosis is induced due to a bacteria familiarized as Mycobacterium Tuberculosis, this bacteria is regarded as contagious as it can transfer from an infected person's cough or sneeze through air and also via saliva [1, 2]. In accordance of the 2017 report by WHO [3], Tuberculosis (TB) is regarded as one of the major root source of the nationwide deaths. Around 10.4 million were diseased with TB and near about 1.7 million died. More than 95% death cases happen in low and middle income countries with India leading the count among the countries contributing in 64% of the deaths. Among the HIV infected TB has been the leading cause of deaths and the areas with pervasiveness of HIV infection have shown a sudden growth in the occurrence of TB infection [4]. A fast examination and treatment of infected ones is crucial for efficiently controlling TB as one person is supposed to pass on disease to 12 to 15 people per year on an average [5]. The transmission is potentially due to the close proximity contacts between the individuals. By obtaining this contact behavioral patterns we can control the spreading of TB. But to accurately obtain the interactions in a particular environment we need to keep a proper check on the presence of number of individuals around and to gather information after short durations which is prone to errors and missing work [6].

RFID (radio frequency identification device) smart sensors are one of the sensors under the Internet of Things which are efficient in detecting objects automatically by tags and readers [7], [8]. This RFID technology can be used for close proximity interactions with high temporal resolution [9]. Thus any close interaction between an infected and uninfected individual can be controlled. The continuous interactions among the devices at different times and different places will generate a large amount of data so for efficient data processing would require large databases and high computation power for checking the spread patterns.

The paper have the following details section 2: Is the related work in the field of tuberculosis, use of IOT based RFID Sensors for monitoring interactions, use of temporal network analysis and Fog computing for RFID readings. Section 3: have given the proposed methodology for detection and monitoring. The Section 4: have given the knowledge of controlling the spread by temporal graph analysis. The performance analysis and experimental setup is given in Section 5 followed by Section 6 which shows the conclusion of paper and of the system proposed.

II. RELATED WORK

Murthy, Natrajan [10] have given computer based system for detecting and classifying TB on the basis of different symptoms like chest pains, blood cough, night sweats and others. In this paper they have evaluated data of around 700 people using the various classifiers like C4.5 decision tree, random forest, support vector machine. Then Naresh, Parveen kumar [11] gave another TB classification system in which they used 667 users for the dataset and gave a fuzzy adaptive network based system and also used partial decision tree for the classification. [12]Erhan, Nejat [13] Orhan, Tantrikulu uses multilevel neural network and genetic algorithms for training of the data set and used C4.5 for the classification of the genotypes. As TB is contagious and transfer via interactions with the infected individual so a large amount of work is done on the social network analyzing for TB infection. [14]Jon, Andre, Kashef investigates the network of transmissions of TB using the dataset created by the maintained excel sheet of jail records of city's TB patients and their contacts with the staff. [15]Patrick, Jennifer, James used the genome sequencing and network analysis to show the socio-environmental factors as the reason of outbreak of TB. The genome sequencing is time consuming but in the proposed system we have used classification of users's level of infection using weka as tool.

[16]Urakawa, Ohkado, L.Kawastu tells that how social network helps to predict who can get infected with TB. Various papers have been written in the past to show how social network helps in checking in spreading of TB but none of them has used an actual monitored interactions, all the network analysis is done by using the written interactions in excel and then analyzing them. So, in the proposed model we have used smart real time RFID sensors which requires the connectivity of the internet. [9] Vittoria, Jean, Ciro have used active RFID for monitoring the proximity of the social interactions and understanding pattern of these interactions. [18] Nicolas, Nagham, Brigitte, Ciro used the RFID based wearable sensors in a hospital for analyzing contact patterns which can help to know spreading patterns of any communicable disease. [19] Kumar, Subhas proposed a RFID enabled mobile based healthcare scheme with cloud. [20] Rajit, Prabhu, Arunabh have given RFID tracking solution based on cloud computing, the main focus is to transfer the data from the readers for greater processing. All the data generated by the tags and readers needs to be saved for assessing we can use the computation power of fog and cloud for it.

[17] Haeng in his paper for healthcare shows how cloud and fog computing complement each other and co-exist. [21] Ahmad, Hussain showed to maximize healthcare services from the cloud by reducing the extra cost of communication and a more real time experience we can use Fog layer between the user and the cloud so instead of remote cloud server access we can have more mobile access to fog servers. [22] Amir, Buyya said that Fog based healthcare systems with IOT will have low latency, location awareness with mobility support. [23] Chang, Satish gave a framework for discovery of fog services of social network in the proximity using mobile ad hoc. [24]Musa with the help of a case study of supply chain management system have used Fog based RFID system for tracking the supply chain with quick real time analysis and response.

III. PROPOSED MODEL

This part gives the proposed model of healthcare framework, which consists of three layers. These layers are depicted in figure 1 where layer one is for accessing the data from the user the middle one is for processing at fog level and the third one is the cloud level.

a. Acquiring data

In this part of the model is used to acquire the personal data of the patient along with the vital symptoms of body. Firstly each of the user is to be registered to the system via using their phone numbers and providing their other personal details shown in the table 1. This will leads to generation of a PID(personal identification) which helps in the further contacts with the user. Then the user will enter the presence or the absences of the TB symptoms as shown in the table 1. These TB attributes are grouped as leading symptoms, progressive symptoms along with the risk factors. The leading symptoms can be observed in any of the user as per their conditions but as the TB bacteria becomes more prominent the body starts showing the progressive symptoms which needs urgent treatment.

A user showing the progressive symptoms is extremely infectious and the uninfected users or the users under high risk of getting infected should avoid physical contact with them. The social physical interaction among the users can cause an epidemic so these interactions are checked by RFID tag attached to the chest of the user. The users with the RFID readers in their mobile phones can sense the tags, the data is sent to the nearest fog server where it does local computation along with processing the request from user and will generate an alert message. All of this data is transferred and saved to the cloud server for further processing.

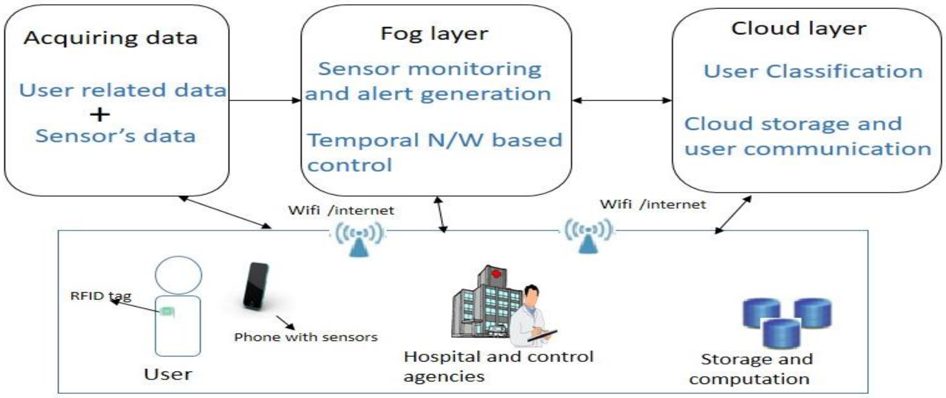

Figure 1: Proposed Method

Table 1: Data acquired

Personal attributes	Leading symptoms	Progressive Symptoms	Risk factors
Mobile number	Fever (yes/no)	Blood in cough (yes/no)	HIV (yes/no)
Name	Chronic Cough (yes/no)	Chest pains (yes/no)	Diabetes (yes/no)
Age	Sputum (high/mild/low)	Night Sweats (yes/no)	Cancer (yes/no)
Gender	Fatigue (yes/no)	Weight loss (yes/no)	Contact with patient (yes/no)
Address	Breathlessness (yes/no)		

b. Fog layer

Fog servers process smart RFID sensor readings, which are taken after every 20 second of interval if any of the contact is made in between that time it is recorded and analyzed. Two users are said to be in proximity in between 20 seconds only and only if there is an exchange of at least one packet among them. Once proximity is established it remains ongoing up till there is exchange of at least one packet every 20 seconds. If any infected user is present in the proximity of contact than an alert message is sent to the user.

In the paper the time is taken as the function to monitor variable contacts between different users to see the local spread patterns of the disease as the global patterns are very vast and make it difficult to monitor the actual super spread. At the local level it would be easy to control the spread. To obtain these local spread patterns Temporal Network graphs are used and temporal network analysis is act as tool for understanding the proximity between the various categories of users. The edges are formed to display the interaction at proximity among the nodes which are the phone RFID sensor of a user and the RFID tag on the other user's chest.

Table 2: Messages to the user

Uninfected	Suspect	Risk	Infected
>Patient need not to be treated for TB >Should stay safe from TB affected people	>Go for a TB conformation test >Take proper medication for TB	>Have high proximity of getting affected >Take proper medication of their ongoing illness >Make proper distance from TB affected people	>Should consult a doctor immediately

c. Cloud layer

The cloud layer has the purpose of storing and analyzing the symptoms of the user which further help in classifying whether user is infected or not. In this part we use J48 classification model to classify the patient on the basis of the TB attributes as class infected, class uninfected, class risk and class suspect. The j48 decision tree algorithm gives the graphical representation of the classification of different attributes of TB for given output classes. For the generation of the J48 tree a machine learning and data mining tool Weka3.9 [25] is used. In figure as we can see a patient falls under class suspect if have a chronic cough with sputum and closeness with any of TB patient. The patient in the class risk are the ones with chronic cough with sputum level mild but suffering from HIV which make them likely to be infected if come in contact with the infected ones. But if the sputum levels are high with the chronic cough and HIV is also positive along with all the advanced symptoms like blood in cough, chest pains etc then patient falls under the infected class. A patient showing none of the symptoms is classified in the uninfected class. Figure 2 is used to depict the classification of the J48 classifier. On the basis of the classification the users are notified with different messages which are depicted in the table 2. For the uninfected may not be having TB but needs to be get checked for other symptoms, for the suspect need to go for TB conformation test, the ones under risk need to control their ongoing diseases mainly and the infected ones need to consult the doctors immediately.

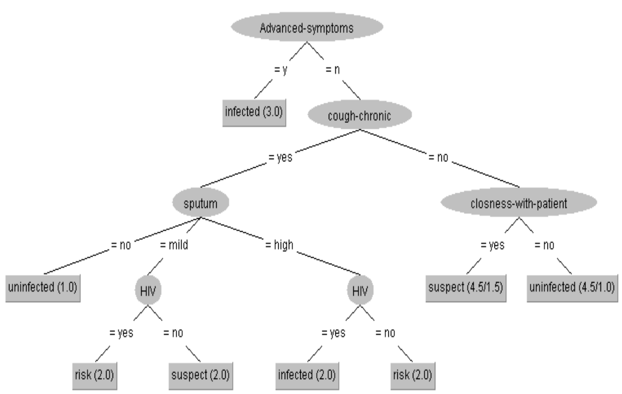

Figure 2: J48 tree for the classification

IV. CONTROL THE SPREADING

The users when are classified as per their category and are provided with active RFID tags on their chest and smart RFID sensors on mobile phones. The RFID devices will share radio frequency packets when they are close proximity range with each other which will lead to an alert generation to the user. These interactions can be monitored at the local level. Temporal graph analysis is used to represent these near proximity interactions where the users are depicted as nodes and their interactions as the edges between the users. A color variation among the nodes depicts the different level of classification of the user. Through the Temporal graph analysis we can tell spread patterns of the TB and also can see the major contributor to the spread and due to the fog layer we can have a local analysis of these temporal graphs. For the generation of the graphs Gephi 0.9.2 has been used.

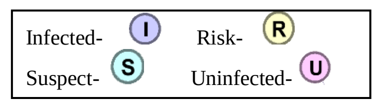

Figure 4: Color variations of infections

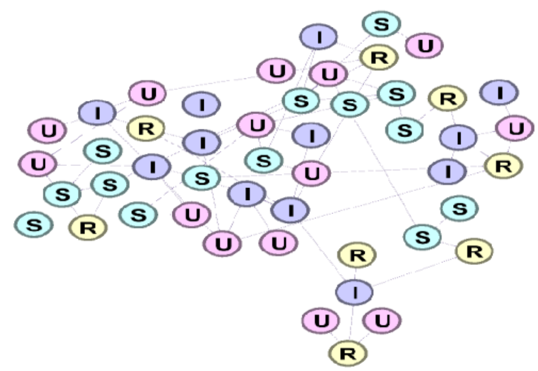

Figure 3: Local proximity interaction

4.1 Creating Local Temporal N/W graph

The temporal graphs will show the edge as the proximity interactions among the two users at a particular time. The users will act as the nodes. These types are based on the timely interactions among the users. The near proximity interactions between infected, under risk, suspects and uninfected individuals are checked by the help of the smart RFID sensors. The Radio Frequency ID tags are present on chest of users infected, whenever they come near the RFID mobile sensors of the other users an alert notification is send to the user. The RFID will send a packet which will thus provide the path to the edge of the temporal graphs. Figure 3 shows the temporal graph interaction at a fog server between I- infected, U- uninfected, S- suspect and R- risk. The color variations will help to understand the interactions easily.

The algorithm 1 is used for the creation and the updation of the temporal network graphs for the proximity interactions among the users under the different categories of the infection.

There are various metrics [26] of the temporal graphs on the basis of which it is evaluated:

Algorithm 1: Generation of temporal graph
Input: Proximity interactions of classified users.
Output: updated or generated temporal network graph

1. For every user
2. Acquire the source personal id (PID) and target personal id (PID) with their classification categories
3. Acquire the start and end time of the proximity interaction
4. **If** the source and target personal id not present **then**
   - 4.1 New nodes for the source and target personal id(PID) is created
   - 4.2 Nodes are labeled and colored with their category of infection
   - 4.3 An edge is created between the nodes
5. Else
   An edge is generated between the source PID and target personal PID

a) Temporal graph for Betweenness centrality: This metric shows how much an infected individual is involved in the spreading of TB among the others.

b) Temporal graph for Closeness centrality: There are certain users which are not in the direct contact of the infected individual but are in the contact of the others which are in the contact of an infected individual. This metric depicts the closeness of every user from the infected individual.

c) Temporal graph for Eccentricity: This metric will depict the how far the infection will spread from an infected individual.

4.2 Global Control

Our main motive is to save the users from coming in the proximity of the infected users. The temporal graphs generated can help in controlling the outbreak of the tuberculosis spread. The local control will take place at the fog level. All the temporal graphs created at the local fog level can send to the cloud for further checking the global spread of the Tuberculosis and to control the spread.

V. Experimental Setup And Performance Analysis

This part of the experimental evaluation of the proposed methodology is subdivided in the three parts as Synthetic Data generation, Classification of Data Using J48 Decision Tree and Computation of Outbreak Metric Using Temporal N/W Analysis.

Table 3: Probability Distribution

Leading symptoms	Probability	Progressive Symptoms	Probability	Risk factors	Probability
Fever	0.04	Bloody cough	0.21	HIV	0.15
Chronic Cough	0.16	Chest pains	0.20	Diabetes	0.05
Sputum	0.17	Night Sweats	0.05	Cancer	0.08
Fatigue	0.03	Weight loss	0.04	Contact with patient	0.12
Breathlessness	0.10	No symptoms	0.50	No symptoms	0.60
No symptoms	0.60				

5.1 Synthetic Data Generation

After a thorough searching of the symptoms based TB data set on internet nothing was obtained so a synthetic data set for the proper evaluation of the system is generated. The synthetic data set is generated in such a way that all the possible combination of the symptoms were taken into consideration. In table 3 probabilities of each of the TB symptoms is listed which are used for the creation of new cases for the data set for TB.

Table 4: Comparison Table

Classification Model	TP	FP	Precision	Recall	Fmeasure	MCC	ROC area	PRC area
J48	0.949	0.015	0.951	0.949	0.950	0.933	0.980	0.919
BayesNet	0.766	0.069	0.803	0.766	0.768	0.704	0.938	0.865
Hoeffding tree	0.927	0.025	0.927	0.927	0.926	0.902	0.968	0.928

The Algorithm 2 displays the steps used for creation of the patient data set. The probability based creation helps in the usage of every high probability case using the individual symptoms probability.

The data set for the contact proximity interactions by RFID is also required for evaluating the monitoring process. So, an actual data set by SocioPatterns [28] is taken which includes the dynamic interaction which took place at a Science gallery with approximately 1400 people and more than 230000 contact interactions among them after a time interval of 20 seconds. Each of the data set containing the source their ids along with the time stamp. From this data set only those interactions were considered that will contribute to a local spread. This data set was used to create temporal network graph for the temporal network analysis.

Algorithm 2: Creation of data set

Input: TB symptoms data along with the proximity interactions

Output: Data set

1. Let k be number of instance which are initialized with 1
2. While k<= number of required users
3. Create a new record by the combination of the TB symptoms values and proximity dataset
4. Assign a new PID to the user
5. If new record already present then discard the new record
6. Else add the new user

Exit

5.2 Using J48 Decision Tree for Classification of Data

The generated data is classified among the different categories by applying J48 decision tree in Weka 3.9. Figure 2- shows the decision tree obtained. A 10 cross validation is applied to the J48 tree for the evaluation of the performance. The categories of dataset is checked and the obtained statistical results are shown in Figure 4, 5, 6, As we can see in Figure 4, J48 classifies the with the accuracy of 94.93% . In the table TP “true positive” gives the correct classifications and FP “false positive” tells the cases which are classified as true but are not. The rate of TP is 0.949 which is high and FP is 0.015 which is low.

```
=== Summary ===

Correctly Classified Instances         543               94.9301 %
Incorrectly Classified Instances        29                5.0699 %
Kappa statistic                          0.9317
Mean absolute error                      0.0469
Root mean squared error                  0.1542
Relative absolute error                 12.6814 %
Root relative squared error             35.8624 %
Total Number of Instances              572
```

Figure 4

The J48 decision tree also provides a high precision 0.951 and recall 0.949 which shows relevancy of classifying instance correctly is high. Similarly F-measure, MCC, ROC area and PRC area are other performance quality metrics with high values 0.950, 0.933, 0.980 and 0.919 respectively. The table 4 justifies and show J48 is better.

```
=== Confusion Matrix ===

   a   b   c   d   <-- classified as
 161   0   0  12 |   a = suspect
   0 156  10   0 |   b = uninfected
   0   6 126   0 |   c = infected
   1   0   0 100 |   d = risk
```

Figure 5

```
=== Detailed Accuracy By Class ===

               TP Rate  FP Rate  Precision  Recall  F-Measure  MCC    ROC Area  PRC Area  Class
               0.931    0.003    0.994      0.931   0.961      0.946  0.985     0.969     suspect
               0.940    0.015    0.963      0.940   0.951      0.932  0.980     0.942     uninfected
               0.955    0.023    0.926      0.955   0.940      0.922  0.976     0.897     infected
               0.990    0.025    0.893      0.990   0.939      0.927  0.975     0.824     risk
Weighted Avg.  0.949    0.015    0.951      0.949   0.950      0.933  0.980     0.919
```

Figure 6

5.3 Computation of Spread Metric Using Temporal N/W Analysis

After the alert generation from coming in the proximity of the other infected users. The tool Gephi 0.9.2 was used for the generation and analysis of temporal network generated by the interactions at the fog level. In order to control the level of spread rates various temporal metrics were evaluated to observe the spread patterns which can help in figuring those users that spread the disease. The basic temporal metric values for Average path length is 1.60, Average degree is 1.22 and Weighted degree is 1.220.

Figure 7 a) shows the between centrality distribution .The between centrality of the graphs helps in finding the mass spreader by showing the involvement of any infected user in the spread. Here the count on y axis represents the number of nodes having the betweenness centrality with the values on the x-axis. Figure 8 a) depicts closeness centrality distribution. The closness centrality gives the relation of the users with any other infected or uninfected user these are helpful in giving the knowledge about indirect spreads i.e. when a user has not been in the direct proximity contact of the infected user but in contact with someone which are in proximity with infected user. In this figure the count on the y axis tells the number of the nodes and the value on x axis is of closness centrality of every node. Figure 9 a) depicts eccentricity distribution. The eccentricity will tell the maximum distance from a particular node to other forming a semi networks. This can basically indicate the different centre points of the network.

All these parameter will help in finding the major spreaders and will help the agencies to help the user with the proper medication or containment so as to control it. The figure 7 b), 8 b), 9 b) are used to depict the temporal network graphs of the metrics evaluated respectively. Figure 10 gives the colour variations as of which moving from left to right means less centrality in the graphs or in other words it shows their less they are not major involved nodes in the spreading.

Figure 10: colour variations

As per the results we can say that Temporal network analysis has been a great help for controlling the spread of TB for the given methodology. For future purpose we can test the working of the system on the cloud services.

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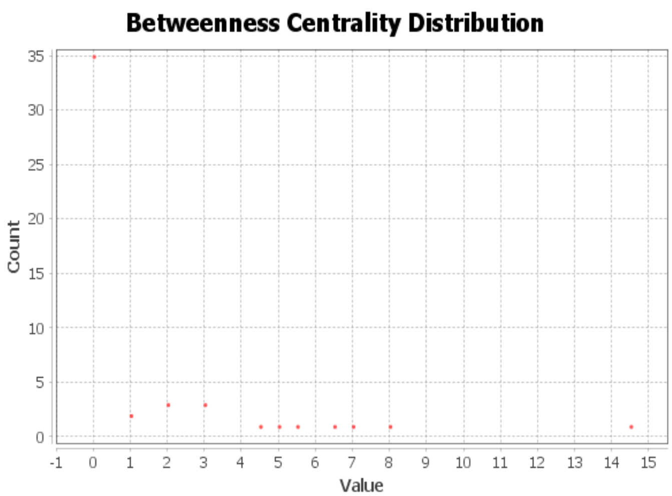

Figure 7 a)

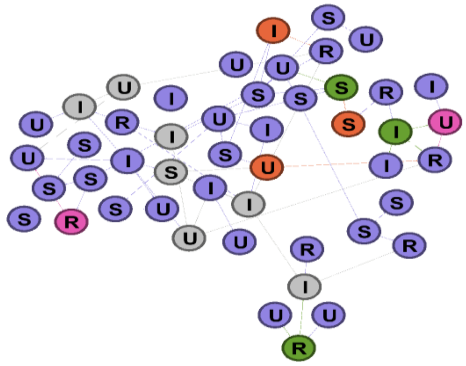

Figure 7 b) Between Centrality

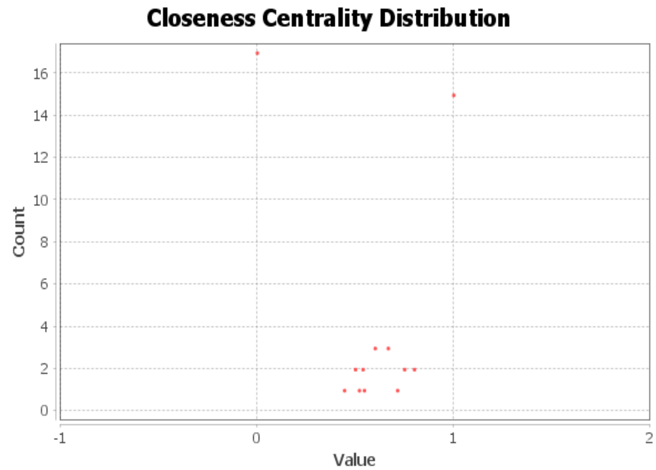

Figure 8 a)

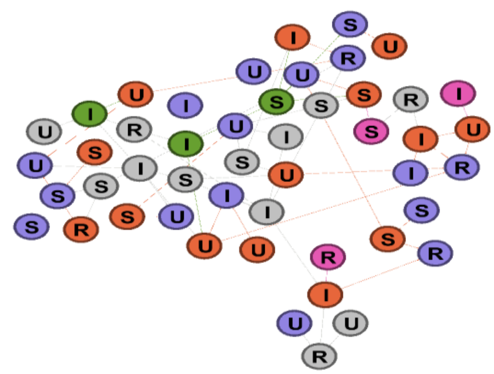

Figure 8 b) Closeness Centrality

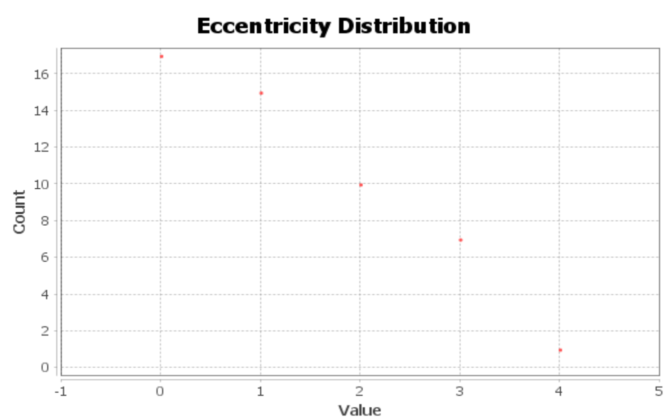

Figure 9 a)

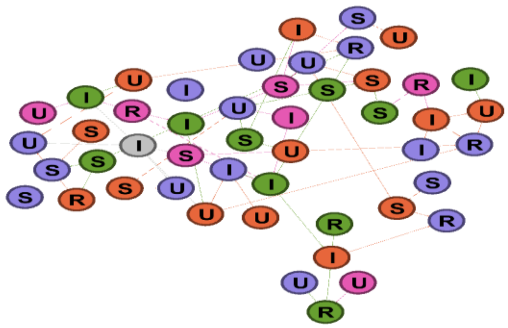

Figure 9 b) Eccentricity

VI. CONCLUSION

TB is considered to be a massive threat for almost all the countries and healthcare agencies. In the paper a cloud computing assisted Fog computing based TB control system is proposed with help of RFID sensors, decision trees and Temporal network analysis. All of the existing work done in controlling TB is offline but in our proposed method we have tried to use a real time approach at a local level by capturing the proximity interactions among the contacts and shooting an immediate alert to the individual under the range of spread. We have used the J48 classifier to classify the users in different categories and have obtained an accuracy of 94.93% accuracy in the classification. Temporal graphs are used to analyse he spread patterns of TB. Temporal network metrics are evaluated to see the users which are most involved in the spread. The result shows that this methodology can be helpful in controlling the spread of TB.

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