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An IoT Guided Healthcare Monitoring System for Managing Real-Time Notifications by Fog Computing Services

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Abstract

Fog Computing is a new computing paradigm which is grown ever since it is being used. It is aimed at bringing the computations close to data sources from healthcare centers. IoT driven Fog Computing is developed in the healthcare industry that can expedite facilities and services among the mass population and help in saving billions of lives. The new computing platform, founded as fog computing paradigm may help to ease latency while transmitting and communicating signals with remote servers, which can accelerate medical services in spatial-temporal dimensions. The latency reduction is one of the necessary features of computing platforms which can enable completing the healthcare operations, especially in large-size medical projects and in relation to providing sensitive and intensive services. Reducing the cost of delivering data to the cloud is one of the research objectives.

Keywords: IOT; Healthcare; Fog computing; Smart devices; Noticification services

1. Introduction

Fog computing is used in customer devices, such as wrist watch, in which it does not only show time, but displays the steps taken by the person including how far walked, and the calories burned. The device can measure the heart-beat and make the person hard or soft sleep. The smart phones nowadays equip themselves with in-built sensors, such as Samsung Note 4 with heartbeat sensors including gyro meter and accelerometer incorporated in smart phones [1].

Fog computing is an extended feature of cloud computing, where both computing platforms have similar intakes which are advantageous to fog computing with use of latency reduction in cloud servers.

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The cloud computing makes a complete package where it comforts the users, but also have disadvantages. One of the advantages of IoT is high-speed processing and computing of big data, generated and managed efficiently in various applications [24]. Smart care systems are needed, in particular, in fast changing pace of human life. When the fog computing and IoT are installed in appliances relevant to medical industry applications, the efficiency of the operations can be improved in such healthcare systems [20].

The new systems are far better than the previous or traditional systems as more reliable and efficient devices are used with data communication technologies that have security compatibilities. The healthcare costs are reduced [10] by installing the fog computing and IoT. With increase in high speed computing and processing, the quality of services is improved. The improvement is seen on a greater magnitude with health monitoring done, based on IoT system with Fog computing [10]. The main advantage of using IoT in medical health care is to decrease barriers in monitoring important health parameters and reducing unnecessary health costs [9]. Wearables are mostly in use in healthcare arena, through which it is the easiest and a comfortable way to gather the data, monitor health and communicate general their practitioners periodically.

The devices and tools that support IoT transform the face of medication through their functions and procedures. For example, armbands, or ECG [12] trackers are behind such devices, relying the hand of IoT platform. The procedures and functions are essential components of IoT for data generation, gathering and management. In addition, the devices analyse data, use a set of rules and algorithms that needed in the analysis. Health trackers appear in huge quantities which work over the largest amount of datasets. Analysis of datasets are performed to know the scale of health related tasks of patients, being the data are from multiple domains and applications. Tracking devices and sensors are attached as wearable tools, like inhalers are attached to trackers for asthma patients. Sensing the change of location, the environment around the patient, monitoring the medication timings are examples of activities of the devices. In addition, the devices and sensors alert with various facts that result large amount of data collection from patients through tracks and notifications.

The article is structured into various sections and subsections. The related work and literature is provided in Section 2. The existing issues and challenges are described in Section 3. Research questions and objectives are provided in Section 4. The motivation, significance and contribution of the research are discussed in Section 5. The methodology, the proposed work and working principle are provided in Section 6. New insights of the IoT driven healthcare systems are described in Section 7. The limitations and constraints of the research are provided in Section 8. The conclusions and future scope of the study are respectively discussed in Sections 9 and 10.

2. Literature review and motivation

The compactness, IP connectivity, low-power consumption and security of patients' data are crucial while designing and implementing mobile healthcare services using IoT. The authors in [9] provide the vital features of mobile health devices. The necessary infrastructure needed in the IoT is described. The authors claim that mobile heath technology can deliver real-time data and support quick diagnosis, remote monitoring and rehabilitation, providing additional advantages, such as reduction of healthcare costs and preventable hospitalizations. The authors report in [23], the necessary concepts and components of IoT needed in the healthcare systems. Smart devices, sensors and high speed internet with high performance computing are discussed providing the need of decentralization of the healthcare services for wider communities worldwide. They describe various features and their development of IoT, middleware and e-health and the associativity between these components. The authors compare the existing technologies providing motivation of new and alternate tools that can provide enhanced healthcare services. The data relevant to blood glucose, electrocardiograms, and blood pressure and temperature measurements are gathered from interconnected devices, suggesting improvements in the follow-up communications with healthcare specialists [15].

Gartner has estimated total number of IoT devices 8.4 billion in 2017 and it is an increase of 31% from 2016. Intel estimates 200 billion by 2020, equates 26 smart devices for each human being on Earth. In terms of cost figures, total amount spent on IoT devices and services is at $2 trillion in 2017, other projections include $772.5 billion in 2018 with 14.6% increase than estimated. It may hit $1 trillion in 2020 and $1.1 trillion in 2021. Healthcare IoT solutions by 2025 may reach around $1 trillion by 2025. According to Deloitte, the Internet of Medical Things may grow up to $158.1 billion in 2022. The following statistics is revealing the use of IoT in healthcare with overall impact in the industry [15]:

1. IoT devices have started commencing in 60% of the healthcare organizations.
2. IoT maintenance and monitoring are ongoing over 73% of the organizations.
3. By 2019, IoT tools and technologies are likely to be implemented in 87% of the healthcare organizations.
4. 64% of patients in the healthcare industry started using IoT tools.
5. However, 89% of IoT security breach occurred in healthcare organizations.

The author in [2] describes an IoT platform with various patient and disease contexts, in particular the Parkinson disease and their symptoms to communicate and discuss with medical practitioners through web interfaces or agent technologies. These technologies are intended to transfer large amount of data from remote locations to the main computing servers. Various features of the IoT have been integrated as discussed in [3] to make well-being comfortable. The method involves numerous devices to acquire large amount of data in seconds from millions of sensors, placed in different geographic locations. Fog Computing is adopted to minimize the delay of travel times from remote locations to further make improvements and offer Quality of Services (QoS) to medical professionals and healthcare personnel. For this purpose, an integrated framework is conceptualized with collaborations among Fog-nodes with other manageable resources and tasks. As suggested in [4], in the context of mobile health, the fundamental characteristics such as compactness, IP connectivity, low-power consumption, and security challenges have been discussed. The authors describe mobile data acquisition methods using various gadgets, wearables to monitor healthy conditions, such as blood-sugar levels, CEG tests, blood-pressure and asthma. Benefits of tools and technologies, such as quick diagnosis, remote monitoring and home rehabilitation have also been described. As suggested in [5] Wireless Sensor Networks (WSNs), health monitoring mechanism is needed for patients, who are at more risk of chronic diseases. WSNs are in wide use, complying with treatment plans and just-in-time safeguard during sudden attacks. Home-based healthcare applications with well-being solutions and remedies using IoT, need connectivity among various devices and their linked sensors in remote locations, transferring data from clouds to edge networks [6, 8].

Fog Computing procedures further facilitate high speed computations locally and communicate their results just-in-time. As discussed in [13], the authors discuss three types of patients, “critically injured” “just generally hospitalized” and “care for discharged patients”. The authors have uniquely described “possessing edge location”, “location awareness”, geographically distributed”, “real-time interactions”, “heterogeneity” and “latency-sensitivity” to make more feasible whether by Fog Computing or cloud computing. Smart way of interpreting ECGs and associated cardiac diseases are discussed in [14]. Various features extracted from smart gateways including heart-rate, P wave and T wave via a flexible template based on a lightweight wavelet transform. The authors reveal Fog Computing achieve 90% bandwidth efficiency with low latency real time at the edge of the network. The authors examine a systematic literature on Fig Computing technologies in healthcare systems to assess previous research as in [16]. The authors in [17] describe e-health gateway implementation for use in the Fog Computing layer, connecting a network of such gateways, both at home and hospitals use. Various application services are discussed with presentation of healthcare scenarios. As discussed in [21], the authors present a survey on the employment of FC to support IoT devices and services using Open Fog Consortium (OFC). Fog Computing architectures are discussed in [22] with various applications from rural areas. The authors in [25] discuss a k-Healthcare model that makes use of 4 layers, the sensor layer, the network layer, internet layer and service layers, all layers cooperate each other effectively and efficiently to provide a platform for accessing the patients’ healthcare data using smart phones.

3. Issues and challenges

Data coming from millions of IoT devices need real time transmissions, monitoring, storing and high speed processing and computations. If the data coming from different geographic regions, multiple domains and applications, the data integration is mere a challenge, especially when it needs connections with the existing healthcare systems. Cybersecurity risks, implementation of IoT technology in poorly standardized security protocols, accessing the sensitive information by hackers are increased risks of IoT. Outdated infrastructure associated with the tools and devices of IoT, insufficient skills needed to operate the devices, no upgrades in the devices are other hindrances to the healthcare industry. IoT and their devices need constant upgrades, poorly managed inventories either patients or resources attached to healthcare industry, overlooking supply and demand, poor quality products and services, breach of customer database systems, and outdated security network metrics are other critical issues of IoT implementation in healthcare industries.

IoT needs connectivity between devices and stores restricted information. Security and confidentiality of personal information are given utmost priority by healthcare organizations. Being healthcare data are sensitive, security and data encryption are critical, even if the data are transmitted in different geographic locations, it is important to be aware of the threats of the added new devices to IoT, ensuring data security and personal safety.

Integration of multiple devices or their associated sensors is an important feature of the IoT, when several healthcare centres needed alignments and connections. But the ambiguity lies with the fact of multiple device integration and the challenge of manufactured devices that may not agree to set of protocols and standards, which can complicate the process of aligning the information. In addition, the same patient may be suffering multiple diseases. Such inconsistencies can create anomalies and ambiguities in device implementations in IoT related healthcare projects.

Data quality is an issue in the healthcare related projects. If the data aggregations are used to explore at a glance and examine the data visualizations, the valuable decisions taken on such anomalous data may go wrong. Especially, when data associated with Big Data are heterogeneous and multidimensional, the data analytics may be erroneous. Being IoT geographically global, it is appropriate to ease the complexity of Big Data with IoT and their linked healthcare data and related Fog Computing services, before their visualizations are taken for interpretations. It is important to distinguish the value and insignificance in the same healthcare data, since both are critical in our visualization and interpretation analysis, thus impacting the decision making process.

4. Research questions and objectives

The research questions are designed keeping in view the literature surveys and the motivation of new technologies in healthcare sciences. How do the IoT driven healthcare systems manage in safe and secure environment? Why do we need a framework and how does it work? How does Fog Computing explore the multidimensional ailments?

The research objectives are designed to depict the IoT driven healthcare systems in safe and secure environment. The description of research framework with new insights of artefacts used in the framework architecture are other objectives. The proposed tools and technologies that can work in difficult environments and implement, where IoT driven healthcare services most needed, are described.

5. Motivation, significance and contribution

IoT should not pose constraints in terms of needs, budgets and infrastructure development. Finding challenges are significant in emerging effective solutions. High speed internet and high performance computing facilities are real motivations of the current research. Prioritizing the project goals that align with the business objectives; models that match with healthcare challenges are significant. Reduce patient waiting periods, attending to emergency calls, tracking hospital and patient movements through alerts need enormous data storage devices and capacities. Healthcare personnel must be careful in treating volumes of patient tracking data on IoT devices and tools, if not treated properly, there may be scope of hacking the trackers and loss of enormous sensitive data. If IoT involves with internet connected to desktops, laptops, smartphones and tablets, professionals are able to communicate and interact variety of users even if remotely joined and operated with notifications and requests. Sensor data come from variety of places and people, IoT devices must be able to sense and distinguish the variety of responses. As an example, consumer groups may have been connected to smart TVs, smart speakers, toys, wearables, and smart appliances. Smart meters, commercial security systems, and smart city technologies that may monitor traffic and weather observance screens are typical industry based IoT devices. Any home and office appliances run on smart devices including smart home and office may be part of IoT infrastructure. IoT device management may include successful deployment of IoT, connectivity, security, interoperability, power/processing capability and scalability, adopting standard protocols by branded vendors and software. Device registration, authorization, configuration, provisioning, device monitoring, diagnosis and troubleshooting are other features of the device management. Deployment of internet based devices that use high speed network, communication and connectivity protocols essentially depend on specific IoT applications.

IoT can offer range of services relevant to consumer electronics, vehicles, healthcare, utilities, transportation, and manufacturing including agriculture industries. The objectives are enhanced quality care, reduced cost of healthcare, improved access to information. In addition, integration of IoT features with medical devices can improve the healthcare services, especially in aging population era, providing constant supervision of elderly patients who suffer

from chronic ailments and keeping them healthy and safe. Patient satisfaction and timely intervention of doctor including more time spent on interaction between patient-doctor consultations are other objectives.

IoT in the populated countries is a healthcare panacea, which has manifold benefits, the most notable benefit is cost reduction and the ratio between patient and medical professional is more. To coup up with patient population and maintaining its balance with medical staff, IoT has definite edge in providing prompt medical services and deliver them swiftly even in inaccessible areas. IoT has significance in prompt delivery of services wherever the patients exist on globally, because medical practitioners can be able to reach through IoT, monitor patient health and recommend necessary timely prescription. Medical personnel need skills how to interpret the data on IoT devices. At times, the data transmissivity may be late, recording may take time and they are prone to errors. If the IoT data systems are connected to electronic healthcare systems, may help minimizing the errors in the data. With increasing number of devices, their responses sometimes may be ambiguous, so it is a challenging task to doctors to come with an appropriate diagnostic solution.

IoT devices are used to acquire and detect volumes and varieties of health points or nodes. The points may be coming from multiple diseases, such as diabetics, blood pressure, heartbeat, brainwaves and breathing patterns. In such IoT environments, health gadgets have definite role to play and many patients depend on variety of IoT products. At times they may not be precise when compared with more reliable on lab based medical equipment. Video cameras and wireless ID cards or wristbands are being used by hospitals. Bluetooth Low Energy (BLE) beacons are being used as a part of IoT technique in healthcare. Staff appointments, location of inventory where the devices, supplies and medicines are checked using tags of BLE. The following is the summary of the significance and motivation:

- Providing Constant Attention
- Building Trust
- Remote Patient Monitoring
- Reduced Costs
- Configuring Emergency Alerts
- Data insights
- Remote medical assistance
- Tracking staff, inventory and patients
- Drugs management

6. Methodology

As per Research Objectives cited in Section 4, more automation is needed in the healthcare industry to bridge the communication gaps between patients and medical practitioners. Slowly the traditional healthcare systems are being replaced by systems of new architectures to manage huge data in one go and the entire procedure cannot work without high speed internet connection with high performance computing tools. The data are in volumes and variety of such Big Data keep arriving from fogs and clouds. In addition, latency is improved with enhanced system response and computations with notifications. The Fog Computing uses local servers to attend and compute system responses rather than cloud servers so as to reduce the latency [11].

Healthcare problems rise in mainly over populated countries where India is one of them as the population is rising day by day and need of helping sick people is rising day by day. The demand for high-quality care is also increased by the population, while reducing the costs of the treatment. The technology is advanced to the level of monitoring health remotely via a machine, which is more reliable than the manual monitoring. It can help in reducing time on the training of individual person and make more reliable on the advanced machines [7].

Fog computing also helps in global positioning system (vice versa) to accurately pin point the location of an individual. The technology can be used to indicate the sudden emergency that has occurred, alerting the doctors that what is going wrong with the patient and what measures are to be taken. The alert can be of different types that use different technology to tell the doctors, as to blink the lights that are controlled by the nodes of the Fog Computing and make a beeping sound while they blink. This may sound very beneficial and good for the people who are sick but the maintenance and keeping the system running like this while maintaining the network and managing are very difficult in Fog Computing, because of unmanageable networks.

With increasing awareness of healthcare, new tools and technologies are taking shape in human life. The health problems can be detected faster as ever before including preventive care of the human body. The impending problems linked with the human body are foreseeable using machine learning techniques. As demonstrated in Fig. 1, the healthcare services are available by Fog Computing servers using various layers. The framework demonstrates various security features that can help protect customers' healthcare data.

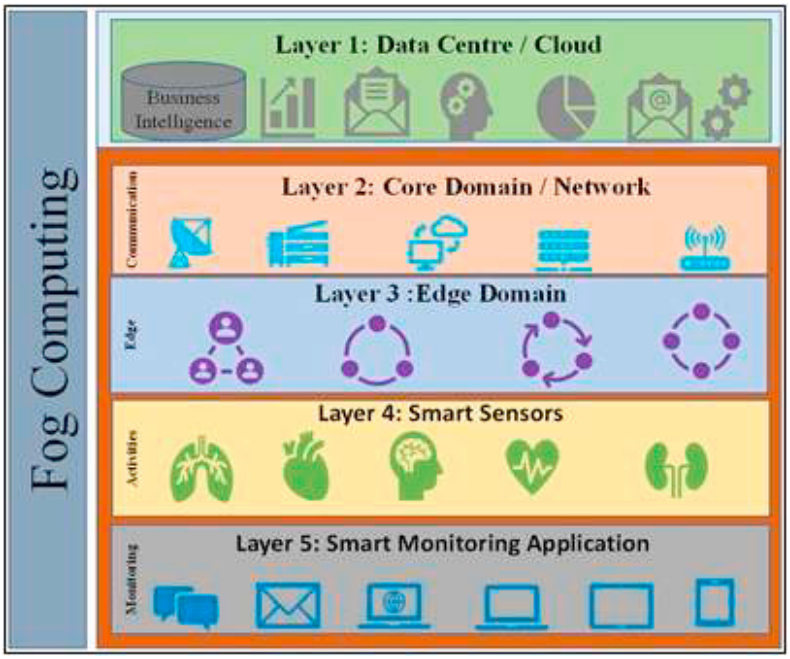

Fig.1. Transmitting data through various layers

As we are aware, the Fog Computing works in between devices and the Cloud Computing, through which an additional processing unit is made available in between the cloud and users to reduce latency, making reliable, energy efficient and maintaining privacy of the system. This gave us additional advantages over cloud computing though both of them have computing power, storage capacity, networking capability and analysing the data in real-time. An alert is popped up on the devices with real time notifications. Fog Computing is done close to the ground, implying that it can reach the users in no time unlike cloud computing, in which latency is an issue.

Unlike Cloud Computing, Fog Computing is not that powerful as it only uses low end computers, personal devices and mobile devices. As the data is being transmitted from the devices to the computing devices of Fog Computing, all the data goes through sections of layers so as to monitor the health conditions from the data. As shown in Fig. 1, the layers are designed in transmitting the data between the devices Fog Computing and Cloud Computing through Data Centre, Core Domain/Network, Edge Domain, Smart Sensors and Smart Monitoring Application layers. The security layer lies between the devices and the computing devices which act like a shield to prevent data corruption. Then the data are transported into the Fog Computing devices that execute all the computing that is required by the user, which is also known as pre-process data. It is not a big data but a small amount of data, which is computed by the devices of Fog Computing. There is an advantage of Fog Computing that it has a temporary storage layer that stores computed data that is sent again later to Cloud Computing for further processing. The network is monitored by the maintenance people whether any fault exists in the transmitting. There are several body sensors developed that are in need. For example –the sensors measure temperature, heartbeat, blood pressure and glucose levels. All the data that are collected by mobile phones and laptops with the help of these sensors are sent to the computing devices, where they are further processed and computed for useful information, delivered to medical staff for interpretation.

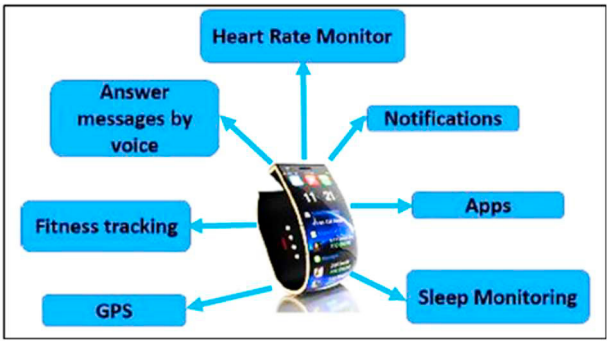

Fig. 2. Real-time notifications in wearable watches

The network in Fog Computing is very complicated and hard to manage and maintain. The security and privacy concerns exist in the Fog Computing, which need to be rectified and improved. The major advantage of the computational service is that it can learn and adapt the possible solutions that are being provided by the Fog Computing. The image in Fig. 2 shows the real-time notification of the calories burned, the blood pressure reported and steps, the person walked.

6.1. Proposed work with new insights

Nowadays, smart watches, phones and laptops are everywhere, serving every possible field. One advantage of the featured devices is that of health and safety of the people. On the other hand, they have computational and processing power to process any given task, which helps people completing their work and enriching healthcare knowledge just-in-time. One of the forms of Fog Computing, affecting our day to day life on daily basis is in the form of wearable devices, tracking everything and everyone in every possible manner. Various sensors are placed in the devices, which are wearable by humans. These devices keep track of various aspects of human life. The wearable devices give a new edge to healthcare but this technology doesn't only enhance in the field of medical sciences but the power of IoT grows in each and every field. These wearable devices are easing and comforting human lives, since they track health information, in addition to safety and security and their linked technologies. The technology has upgraded itself in such a manner that it can now provide the services of tracking heart rate, steps count, oxygen level, timer services of this kind are available at a common platform for everyone to use it (Fig. 3). The smart watch is a new upcoming technology and helps people to stay fit.

Fig.3. Smart features in clothing

The people with high blood pressure or high heart beats problems can become peaceful as they have now this smart watch which does the work for them. The data containers need not be in sync with the devices as they are already

stored in the containers [1]. There is one more feature of Fog Computing where it can filter the data, which can result in reducing the load and stress on the networking lines. New architectural frameworks with design and development of artefacts that represent the constructs and models and interconnect the healthcare features that can describe various entities and dimensions, such as smart features in clothing may be offered to medical and healthcare professionals.

6.2. Working principle

The smart watches and phones are the key elements to save one's life. Whether the person is sick or not, the devices can tell the person, if he/she is alright or not. While the exercises are taking place, the people may be relieved of the stress. The sensors help even the fit people to stay fit as the sensors reveal the calories burned by them while exercising so that they keep on working hard and stay fit. The smart watches in healthcare sector have progressively grown. Even smart goggles can help to locate through smart GPS systems (Fig. 4). The devices are no doubt set to change the face of technology in the coming future.

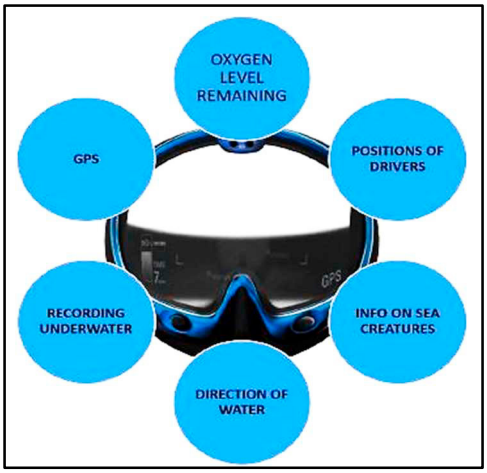

Fig. 4. Smart goggles

The paper is focused on the topic of healthcare using IoT in real-time notification by the help of Fog Computing which does all the computing and helps the doctors to understand well the illness of the patient. The tools help the ill people to know what is ailment and what they are supposed to do. The data which is being processed are not that secured even if there is a security layer in between data transmission and communication layers. Now the technology is so advanced where the patient need not be admitted into the hospital forever, as the patient can go home and be free.

7. New insights of IoT driven healthcare systems

As per Research Objectives cited in Section 4, we need to focus on building larger integrated frameworks that can facilitate collaborating and connecting healthcare services in remote rural areas with urban city centers. With the advent of Big Data and new data and business analytics, there is scope and opportunity of building innovative and semantic based data constructs and models that can facilitate and make connections between multiple activities, functions and operations of healthcare systems. Various frameworks are in place to build metadata and meta-knowledge of healthcare cuboid structures for data mining and visualization [18, 19]. Frameworks constructed for healthcare systems, in particular complex disease systems, provide new insights for representation of healthcare data science and new knowledge discovery needed for medical practitioners [19]. Data views can be extractable from these integrated frameworks and generated metadata cubes, which can readily be used for interpretation of patient complaints, analyze and discover new meta-knowledge of diseases and aliments of the patients. Documentation, organization of data sources and their modelling are added motivations to create new insights and data views from

IoT driven metadata cubes. These are new motivating concepts and tools that can be offered to healthcare professionals.

8. Limitations

One of the main issues with Fog Computing is the lack of security. When the data are not properly protected, there is a danger that clients or patients' data might be stolen. The data are very confidential and if stolen, it might become a very big problem for the hospitals and other organizations, subsequently the people might not trust that organization or hospital. Neglecting the security services of data can undermine the safety patients and their records.

The security is not that powerful as the devices that are being used in the computation and processing are normal smart devices. They need to be updated by the developers of the devices. If the devices are not updated, then there is a risk of data being stolen very easily. The risk of losing the users exists in the business. The security is the main concern with the Fog Computing and also the smaller screen in the devices like smart watches, where the text and screen is very small. It is problematic when typing text messages to someone.

9. Conclusions

The systematic literature survey done on IoT and Fog Computing tools and technologies suggests new scope and opportunities of mobile healthcare in rural villages to connect to urban cities, where massive computing facilities are made available by different healthcare institutions. In addition, broad-band internet connectivity with added 4G and 5G communication technologies can support the IoT and Fog Computing facilities worldwide.

For successful implementation IoT related platforms, the integrated frameworks need to be designed, developed and collaborated with various tools and devices in Big Data scale, so that IoT products and services can reach geographically. Since many functions, activities and tasks are involved in the IoT driven healthcare infrastructure, definitely Fog Computing can benefit successful implementation of IoT in the healthcare sector. The computations are necessary in all health-related work and tasks. They are controlled by applications, performed and executed in between clouds through multiple physical sensors that are located in the medical institutions, even directly from patients. In spite of advantages, the Fog Computation has some major disadvantages including challenges which cannot be resolved such as one devices which is computing everything and because of the fact the technology is still in developing stages. The new technology of smart watches has small screen and not good for typing. Not only the Fog Computing focuses on computing aspects but also on networking and clearing congestion aspect. The Fog Computing appears to be not an option, but helps in providing a good care to those people who are sick and need immediate healthcare services at remote locations. IoT may renovate and revolutionize the healthcare industry, in which the patients, medical practitioners and industry associated specialists are all beneficiaries as long as the data security is addressed in the industry.

10. Future scope

The wearable smart watches can create many more opportunities for everyone at any given period of time. These devices are light weight and so compact than the mobile phones and laptops and people tend to use these devices much more in the years to come. The devices become the future of the upcoming generations. The devices can perform every task that laptop and mobile phone perform, easing the life of the people. They are alternatives of mobile phones and laptops. The Fog Computation cannot perform large scale task and processes, but is more reliable and dependable [26] than Cloud Computing. Smart watches have wearable technology, with digital power, displaying heartbeat, blood pressure, and calories burned. IoT driven healthcare technology with Fog Computing facilities appears to dominate the healthcare industry many years to come.

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