# Analysis of Risk and Security Within Fog Computing-Enabled e-Healthcare System in Uttarakhand

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**Abstract** With the advent of fog computing, various e-governance services get influenced as fog provides new service delivery models and new ways to interact with the citizens. Uttarakhand, as a state of 86% hilly region and 65% of forest area, got geographical conditions that are not so favored for cloud-enabled technologies, because cloud needs regular and high bandwidth Internet connectivity. Fog computing can be a key player, in terms of providing e-Governance service. E-Health is the major service provided under the e-governance platform. With the application of Internet-enabled and IoT-based e-Healthcare systems in the state like Uttarakhand, there can be a drastic improvement in health services. E-Health services require real-time processing, low latency, high consistency, and high data rate, and these all parameters are fulfilled by fog computing. There are many kinds of research that describe how fog can be used in e-Healthcare systems. In this research paper, we discuss fog computing in the context of Uttarakhand. Our main concerns are security issues and challenges faced by fog computing while using the E-Healthcare system in hilly areas of Uttarakhand. In studying those challenges and security issues, the technologies related to fog computing are also discussed.

**Keywords** Fog computing · Internet of Things · Cloud computing · e-Health care · e-Governance

## 1 Introduction

Uttarakhand is a state of the Himalayan region that has very different geographical conditions than other states in India. Many services and applications use Internet of Things (IoT) today, due to a variety of sensor availability, low-cost Internet, and cloud services [1]. Technology like IoT and fog can be installed within the people's

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K. Khanna et al. (eds.), *Cyber Security and Digital Forensics*,
Lecture Notes on Data Engineering and Communications Technologies 73,
https://doi.org/10.1007/978-981-16-3961-6_3

range and serve them with different offerings. One such important e-Governance service provided by fog computing is in e-Health care. It also raises the patient's life quality by providing real-time health data analysis [2].

IoT extends the services drastically that are traditionally given by Internet-based technology. With the advancement in sensors used in IoT, the data collection techniques raised their standards significantly. CISCO forecasts that the size of data accumulated by IoT devices may reach 600 zeta bytes per year by the year 2020 [3]. When this large amount of health data gets transferred between devices and the cloud, it creates the problem of low latency and system idleness. As we are concern about e-Health implementation, the above-stated issue represents some difficulties in how to deal with a large number of accumulated health datasets to keep low latency in real-time applications [2].

Fog computing solves some of the difficulties raised by the cloud of things (CoT). Fog computing has the potential to give reasonable answers to all issues related to the use of IoT and cloud in e-Healthcare applications. In the E-Health solution, all the data gathered from IoT sensors must not be transferred to the cloud, some can be interpreted at the data generation point, and the processed information is then transferred to cloud or any other device for further usage. This can only be done with the help of fog computing [1].

E-Healthcare platform consists of applications and services used to gather and provide clinical data [4]. Our main focus in this research is to figure out the risk factors involved in fog-enabled e-Health system in Uttarakhand. The cost will also cut down because the patient does not have to come to the hospital for monitoring purposes, they can be monitored remotely with the help of fog architecture [5].

The present research gives the details of fog-enabled e-Healthcare systems. This research also gives the main characteristics of an e-Health system combined with fog computing. Some of the main objectives of this paper include

i. An overview of e-Healthcare systems in Uttarakhand.
ii. An investigation of how e-Health applications profit by the fog computing.
iii. Present the various terms in a presentable way, so that it can be understood why these technologies are collaborating.
iv. Finding the risk of involving fog in the e-Healthcare system in a state like Uttarakhand and analyzing them.

## 2 Methodology

This is a descriptive study in which several published reports, research studies, articles, e-books, vulnerabilities notes, and government notifications are used as the secondary data source to assess and analyze the security vulnerabilities in popular web browsers. To gather the secondary data, Google Scholar (https://scholar.google.com/), Directory of Open Access Journals (https://doaj.org/) and Connecting Repositories (https://core.ac.uk/) are used. Appropriate search keywords are used to find the requisite data on the above-used databases, such as e-Health, fog computing, cloud-based e-Health system, fog-based e-Health system, e-Health in Uttarakhand, etc. Further, the data is reviewed and analyzed accordingly to the objectives of the study.

## 3 Overview of Key Technologies

E-Health care is the utilization of data and correspondence innovative technology in health care and is viewed as basic for an advanced, financially savvy health administration system that is prepared to address difficulties and challenges. Various technologies are combined to provide the foundation for an e-Healthcare system. In this section, these technologies are discussed as follows:

**Internet of Things—**In recent years, devices are developed with the inbuilt feature of Internet communication. These smart devices or things can communicate with each other via the wireless network. Devices can be hardware, software, or even physical objects that can talk to each other [6]. With its rapid advancement and low cost, IoT will be very beneficial if included in the healthcare environment. Using data gathered with IoT sensors, one can advance his decision-making abilities, and when used in health care, doctors or health managers can take quick and decisive measurements for the betterment of patients. The patients also take part in the system actively and contribute by checking and maintaining their health records and IoT devices [5].
**Cloud Computing—**Cloud computing as defined by NIST is a pool of shared computing resources accessed on-demand on a network [7]. Computing resources can be shared with the help of three service models (SaaS, PaaS, and IaaS) and four deployment models (public, private, hybrid, and community) [7]. Scalability, rapid deployment, and low cost are the key characteristics of cloud computing. Consumers can use, switch, or end any computing service automatically according to its need [2]. One of its main advantages is the availability of enormous data storage capacity.
**Fog Computing—**Fog computing was characterized by Cisco as an amplification of cloud computing where data is stored at the edge to raise the standard of services with low latency and high data analysis [1, 8]. It has the same features as implemented by the cloud, i.e., computation, storage, and services, etc. Fog processes data and can segregate and transmit it after analyzing, resulting in time and resource saving [9].
**The Network Technology Used in IoT, Cloud, and Fog Computing—**The network is also a vital player in using IoT, cloud, or fog. Some of the important network technologies used are discussed here:

(i) *RFID*—The short-range communication can be done by using radio frequency identification (RFID) for each device used in the network [10]. RFID can be very well suited for healthcare fog devices, as these are cheap, reliable, and trackable.

(ii) *Bluetooth*—Short-wavelength UHF radio waves are used in this standard to exchange data between mobile and fixed devices from 2.402 to 2.480 GHz [11]. It can provide speed up to 3 Mbps over a range of 100 m.
(iii) *WiFi*—WiFi is one of the main network technology used in IoT. This is the method through which millions of devices are connected to offer Internet-based services [12]. Some WiFi exceeds the speed of 1 Gbit/s over a range of 100–150 m. Most of the healthcare environments in hospitals have a WiFi network available. WiFi can be accessed with mobile devices as well as wearable sensor devices, which makes it a highly commendable option for fog computing.
(iv) *WiMax*—WiMax provides a range of up to 50 km. It is best suited for communication between fog nodes that are in different parts of a city. Different standards of WiMax starting from IEEE 802.16a to IEEE 802.16c provide flexibility in choosing bandwidth range from 2 to 66 GHz [13].
(v) *Mobile Network* (*2G, 3G, 4G, LTE, 5G,* etc.)—The use of mobile in IoT and fog is a necessity without which the concept does not work. 2G, 3G, 4G, LTE, and 5G are the cellular technology known to use for long-range connectivity wirelessly [14]. E-Healthcare facility uses a mobile device and network to authenticate and share information and services. Long-range connectivity is also needed for healthcare facilities in Uttarakhand state. Cost-effective development in smart devices in recent years allows common people to use its services and connect to the world with the latest technology [14].
(vi) *WSN*—Wireless sensor network or WSN is a network of geographically detached sensors that are used to take care of physical environments [15]. Information assortment and transmission are the essential activities of WSNs [16]. And, like IoT, fog is dependent on their sensors for data collection; therefore, WSN has the advantage to be used in these technologies. The advancement of detecting IoT devices makes WSNs continuously develop into a classic detecting stage, which can give information mindful administrations to a variety of uses [17].

## 4 Background Study

This section is to study the work done by other researchers to get an understanding of implementing fog computing-based e-Healthcare systems in rural areas of Uttarakhand. Fog computing is becoming an important delivery model of Internet-based services. Implementing fog gives benefits as well as some disadvantages to be discussed. This section will be focused on getting and reviewing the work in the last few years implemented in this area. The aim of getting the gray area (security challenges) will also be done through this literature review.

Kuo [18] described and focused on the use of cloud computing in the e-Healthcare environment. In the research paper, Kuo elaborated on the challenges of cloud computing some are lack of trust by the user, cultural resistance, not defining proper service level agreement by the service provider, data lock-in, low latency, and virus in distributed cloud systems, etc. Many other security issues are discussed in the paper with a detailed explanation.

Alharbi et al. [19] study the role of cloud base e-Healthcare applications in the context of Saudi Arabia. The study provides a business perspective on the healthcare model and shows its cost effectiveness. Habiba et al. [20] give the security issues involved in the cloud computing identity management paradigm. They analyze various cloud identity management systems and discussed their security issues and also provide ways to solve these vulnerabilities.

Ouedraogo et al. [21] address the lack of transparency in security models of cloud, whereas Hashizume et al. [22] discussed the differences between vulnerabilities and threats and created a relationship between them. Then they also proposed new security techniques to mitigate these threats. Wang et al. [23] dissect the productivity, avg. frame rate, delivering execution bottleneck of the cloud delivering framework, and set forward an extraordinary boundary change technique to improve framework execution, by advancing related server and delivering machine setup. They conclude that an increase in the number of users directly increases the average response time, i.e., low latency.

Mitton et al. [24] include sensors in cloud computing in their research. They coined the name sensing and actuation as a service (SAaaS) for this architecture. This architecture is used to provide sensors and actuators as a service to the user. And the cloud is involved to give the computation and data storage benefits. We can also say this as CoT, i.e., cloud of things.

Ibrahim et al. [25] defined the term fog health as the inclusion of fog computing into the healthcare paradigm. They also recapitulate the issues in the domain of fog computing and health care. From their literature review, they found that low latency and slow data analysis are the main issues in distant healthcare monitoring systems. Silva and de Aquino Junior [26] also consider low latency in cloud computing as one of the main issues that can cause a failure of the healthcare system. Fog-enabled healthcare systems are liable to solve the problem of low latency. Therefore, the authors suggested the use of fog computing in this area for solving much of its issues. They also figure the lack of well-demonstrated architecture of fog-enabled e-Healthcare systems. Vilela et al. [2] present a review of the application and challenges of the fog-enabled e-Healthcare system. They summarize the already available solution to the problems raised within the system like latency, security, privacy, etc. They also study communication protocols used between edge and cloud computing.

By introducing fog computing for various e-Health services that are previously delivered by cloud computing, most of the vulnerability (issues) can be solved. But whether these services are beneficial and practical if implemented in rural and hilly regions of Uttarakhand, we will study the challenges that have to come in those distant areas.

## 5 Healthcare Scenario in the Himalayan Region (Uttarakhand)

Admittance to medical services in the rural parts of Uttarakhand keeps on being poor. Given the limitations of territory and geology and the small and dissipated nature of the provincial settlements, expanding access represents a significant challenge. As most of the people living in hilly areas are poor, they cannot bear the cost of the significant expense of private clinical consideration. There is an intense lack of different healthcare human resources in the state-run Primary Health Centers (PHC). Almost 90–94% of physician's posts are vacant in the state. In hilly areas, there are only two PHC which are operational per 100,000 peoples [27]. This shows that the ratio between health facilities and patients is very low. This scarcity leads to the unsuccessful implementation of health services provided by the government [27, 28]. For raising the standard of healthcare facilities and improving the service availability to common and poor people, there should be a mechanism that will address the problem in hilly and rural areas of Uttarakhand.

In the Himalayan state, Uttarakhand, initiatives are been taken by the state government to fulfill the need of people for e-Healthcare services. Many projects are going on successfully like [29].

The e-Health services (Table 1) that are started by the Uttarakhand Government are unproductive due to lack of Internet infrastructure and awareness. Expanding and reinforcing the quantity of health facilities focus that could work nonstop, particularly in rural zones, would go far in diminishing the health problems in the state. This can be done if health facilities are incorporated with fog computing. Using fog computing for providing e-Health services can help in the timely recognition and avoidance of diseases.

Several healthcare services can be provided by incorporating fog computing in e-Health systems like smart health monitoring systems/smartphone-based e-Health solutions [30], home healthcare systems [5], collecting health data in real time [9], automatics dialing of emergency numbers, hospital e-Management [5], etc.

**Table 1** Various e-Healthcare services running in Uttarakhand

| e-Healthcare service | Benefit/Use of service |
|---|---|
| e-Parchi | Outpatient department (OPD) registration system |
| e-Attendance | Attendance tracking of medical staff |
| e-Aushadhi | Record of medication data from providers to the stockroom to healthcare offices to patients |
| e-RaktKosh | Online facility to collect blood, plasma, and platelets |
| 108 Services | 24 $\times$ 7, toll-free emergency telephone number for calling Healthcare ambulance from any location within the state |

## 6 Security and Challenges

This section gives a clear idea of security and challenges that must be covered to build a reliable, user-friendly, manageable, and secure fog-implemented e-Healthcare system. Fog provides many advantages to authorities and patients, also enhances the quality and effectiveness of the various services provided by healthcare systems. In a region where demographic conditions are not-so-good, fog-based e-Healthcare systems can provide an expert solution to the health problems of the citizen. As there are several merits, fog also has some issues that must be addressed before applying it to healthcare systems. Fog-based healthcare system manages very sensitive health datasets, so security is the main concern while using it.

Important security concerns/challenges in fog-based e-Healthcare system are as follows:

**Safety of Healthcare Data—**Safety of data is the main concern in the healthcare system. Patient-related data that is generated through IoT sensors is very much sensitive and should be handled carefully [9]. Data security concern contains issues like illegitimate data access, data changing and removing issues, ownership changing issues, and data sharing with other users. With the said issues, there is a very high risk of illegal file/database access in the fog system. Data should be encrypted with secured keys and transferred via secured socket layer (SSL) for maintaining data security. Ownership access should be managed securely so that the user cannot view the health dataset of other people.

**Wireless Security Issues—**Generally, a wireless network is used between fog devices for data communication [31]. This network is also vulnerable to various attacks like data infringe, losing data in-between communication, IDimitation, communication response attacks, etc. This can result in low privacy, inadequate accuracy, and also lower the trustworthiness of the system. Encrypted communication is a way to overcome this type of attack. Proper authentication and secure data routing will enhance wireless security features.

**Computer Virus—**These issues are related to computer viruses like Trojans, malware, worms, spyware, etc., which can degrade the performance of the system and can also spoil the health data permanently. Various antivirus programs are available that can be included in the system, for getting rid of these computer viruses. Data backups should be taken periodically to overcome any such vulnerability.

Although monitoring the health of old age people become very easy if we include fog computing into the system, this system is tracked with the help of a mobile phone. There is also a problem with aged people as they are almost unaware of modern gadgets like smartphones, etc., and they are not able to use them efficiently and accurately. This is a major challenge in applying smartphone-based technology in health care.

## 7 Conclusion

Despite various improvements in the health infrastructure in Uttarakhand, there is a shortage of health personals and primary health care centers. The geographical condition is also not very favorable for infrastructural development. An insufficient number of trained health personals give rise to the system that enables to monitor the health of people without much human intervention. Fog computing-based e-Healthcare system provides a way to enhance the capability of health monitorial without including trained health personals, as almost all the monitoring is done by the IoT and fog-based sensors. So this technology enhances the option of giving better e-Health solutions to the distant people of Uttarakhand. There are a good number of benefits seeing we can suggest fog computing as a technology that can change the scenario of health facilities in Himalayan regions. But there are some security issues and challenges also that must be entertained before proceeding further. For future work, we are working on an architectural model of a fog computing-based e-Health system that includes RFID, NFC, LWPAN, and other WiFi technologies so that the healthcare department gets benefitted from these advancements.

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