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Mist Data: Leveraging Mist Computing for Secure and Scalable Architecture for Smart and Connected Health

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Abstract

The smart health paradigms employ Internet-connected wearables for tele-monitoring, diagnosis providing inexpensive healthcare solutions. Mist computing reduces latency and increases throughput by processing data near the edge of the network. In the present paper, we proposed a secure mist Computing architecture that is validated on recently released public geospatial health dataset. Results and discussion support the efficacy of proposed architecture for smart geospatial health applications. The present research paper proposed *SoA-Mist* i.e. a three-tier secure framework for efficient management of geospatial health data with the use of mist devices. It proposed the security aspects in client layer, mist layer, fog layer and cloud layer. It has defined the prototype development by using win-win spiral model with use case and sequence diagram. Overlay analysis has been performed with the developed framework on malaria vector borne disease positive maps of Maharashtra state in India from 2011 to 2014 in mobile clients as test case. Finally, It concludes with the comparison analysis of cloud based framework and proposed *SoA-Mist* framework.

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Keywords: Mist Computing, Fog Computing, Secure Architecture, Smart Health, Big Data Analytics.

1. Introduction

Sharing, storing and processing of public geospatial health data requires secure infrastructure. Geospatial Health data could be analyzed for locating the area with critical issues of diseases so that proper healthcare facilities could be provided. In many cases, propagation of diseases and ailments are somehow related to geographical location, e.g. Zika Virus in Puerto Rico *etc.*. Fog computing could be leverage for enhanced analysis of real-world data about diseases

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and other problems along with the locations¹. Geospatial Health data are heterogeneous that lead to challenges in integrating it with existing healthcare facilities, interoperability *etc.*. Both fog and mist Computing are the emerging solution that provides low-power node for increasing throughput and reducing latency near the edge of various systems at client layer^{2,3}. Mist computing requires less cloud storage and transmission power for long-term analysis data. Fog computing has been applied successfully in healthcare and smart cities^{4,5,6}.

Mist computing environment provided low-power gateway that increased throughput with reduced latency near the edge of clients. Consequently, the cloud storage has reduced. In addition, reduction in the required transmission power results in overall efficiency. The geospatial health data were processed at the edge using proposed secure Mist-based architecture. The present research paper has made the following contributions to the secure transmission of health data:

1. Proposed of *SoA-Mist* i.e. a four-tier secure mist computing based framework that allows communication between client layer, mist layers/nodes, fog layer and cloud layer for enhanced security features for geospatial health data sharing in secure and more efficient way.
2. Sketched the prototype development by using win-win spiral model. The interaction between the various services modeled by using Unified Modeling Language (UML) with use case and sequence diagrams.
3. Performed overlay analysis of malaria vector borne disease positive maps of Maharashtra, India from 2011 to 2014;
4. Presented the comparison analysis of cloud computing with proposed framework.

2. Related Works

2.1. Edge Computing

Variety of Data are processed and produced at the edge of network and some works have done before in micro data center and cloudlet. Edge computing allows for more edge devices to interface with the cloud in larger scale. Since the cloud computing environments are not setup for the velocity, variety and volume of heterogeneous data items. It changes in the systems before cloud must be adapted to improved make use of the cloud services accessible. In the edge computing concept, the things are data producers and data consumers. At the edge, the things are perform the computing tasks from the cloud as well as request service. Edge computing can perform data storage, offloading, caching, computing, processing, delivery service and distribute request from the cloud computing layer to client tier layer. With the verity of jobs in the edge network, the edge nodes need to be well designed to meet the requirement efficiently in security, reliability, and privacy protection service. In edge computing, it requires to put the computing at the proximity of data sources. These have been great benefits as compare to the traditional cloud computing paradigm^{6,7}.

2.2. Cloud computing

Cloud computing paradigm has provided huge storage and computational infrastructure for geospatial data analysis. It facilitated a transition from desktop to cloud servers. Cloud computing along with other web architectures have created an open environment with shared assets⁸. Cloud framework delivered a robust platform in organizations that interrelate technologies, tools, and expertise to nurture production, handling and use of geospatial data. This integrated hosted service method helped in installing patches and application advancements for users transparency. The another characteristics was geospatial web services as an established architectural methodology. Many cloud platforms uncover the application functionalities through geospatial web services⁹. This permit clients to query and update different types of cloud services. It also has provisions of a typical tool to assimilate different cloud applications in the software cloud with enterprise Service Oriented Architecture (SOA) infrastructure. Figure 1 (a) shows systems' view of Cloud Framework for sharing and storing of health data¹⁰. In client-tier layer, there are three types of clients namely mobile, thick and thin. Clients visualize and analyze the geospatial data. Mobile client operates though mobile devices whereas thin clients works on standard web browsers. In thick clients environment, users process or visualize the geospatial data on desktops that requires installation of additional software for full-phase operations¹¹. The cloud layer is comprised of main geospatial services executed on the servers. It is intermediate between service providers and clients. There are different type of services such as, Web Map Service (WMS), Web Coverage Service (WCS), Web Feature Service (WFS), Web Catalog Service (CSW) and Web Processing Service (WPS) that operates on top

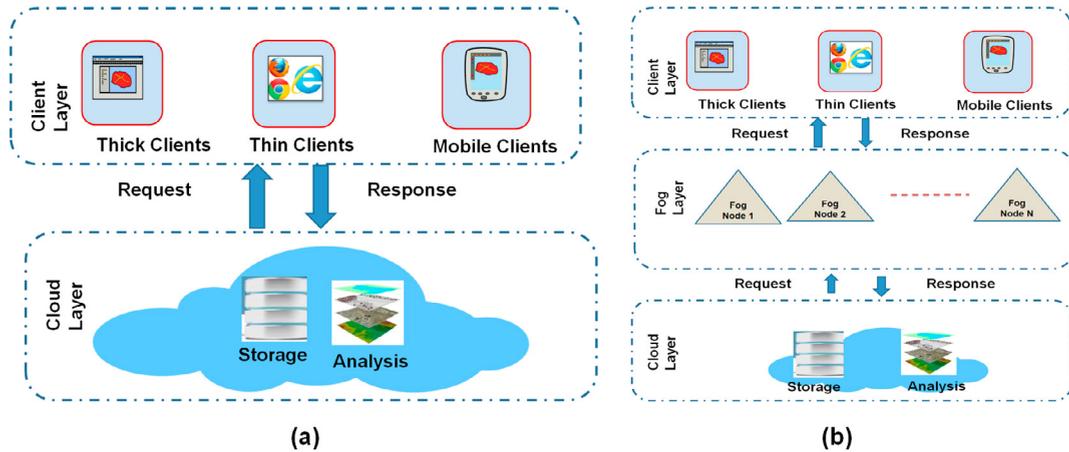


Fig. 1. (a) System overview of Cloud framework with three types of clients as thick, thin and mobile clients. It has client layer and cloud layer with different web services for storing and analysis of sensitive geospatial health data¹⁰ (b) Conceptual diagram of the Fog framework for power-efficient, low latency and high throughput analysis of the geospatial health data

of dedicated servers⁹. In cloud layer comprises of storing and analysis of the various geospatial data. System utilizes the layer to store, recover, manipulate and update the geospatial data for long-term analysis.

2.3. Fog computing

With the technology enhancement of fog computing, it has given the more computing power to the cloud framework. Fog framework has three layers as client tier layer, cloud layer and Fog layer. Fog layer works as middle tier between client layer and cloud layer. It has experimentally validated that the Fog layers are characterized by low power consumption, reduced storage requirement and overlay analysis capabilities. In the Fog layer, all the Fog node developed with Intel Edison processor. Fog framework used to assist and hence enhance the capabilities of cloud framework. In Fog framework, fog node processes the data. After processing, it has the ability to send the data to cloud layer for long-term storage and analysis. So, Fog framework enables the more power to the end-users for better performance without computational overhead at cloud layer. Figure 1 (b) shows the Conceptual diagram of the fog framework for geospatial health data storage and analysis^{5,4,12,13,14}.

From the above conceptual diagram of cloud and fog framework, it observed that the geospatial data as a key components for data analysis in cloud layer^{11,10}. It requires geospatial data from the various components. It led to the concept of geospatial big data that is discussed in the next section.

2.4. Big Data

Big data have included data sets with huge sizes beyond the ability of used software tools to capture, manage, accurate and process data within an acceptable elapsed time¹⁵. Big data can come in multiple forms. Most of the big data are semi-structured, quasi structured or unstructured, that requires numerous techniques and tools to analyze. Analysis of big datasets can discover the new correlations to spot business trends, prevent diseases and combat crime. Big data sets are growing rapidly because they are increasingly gathered by the information sensing mobile devices, microphones, wireless sensor networks, cameras, aerial images and software logs^{16,17,18}. Geospatial data are always been big data with the combination of remote sensing, GIS and GPS data. Now-a-days, big data analytics for geospatial data are getting considerable attention that allows users to analyze huge amounts of geospatial data. Geospatial big data usually refers to geospatial data sets beyond the capacity of present computational environment¹⁶.

As we know that the reliability, manageability and cost saving are the key important factors in that cloud computing always be one of advantageous over other emerge technology for data processing. But in terms of security and privacy are the main concerns for the processing of sensitive data. Particularly in health sector, data are so sensitivity for further processing and analysis¹⁹. Particularly, for health sector, disease data sharing has been a significant issues for the collaborative preparation, recovery and response stages of numerous disease control mechanism. Disease phenomena are strongly associated with geospatial and related temporal factors. For tackling these situation, Cloud

framework has provided dynamic and real-time way to represent disease information through the maps on common browsers^{2,5}. So for sharing and analysis of health data in secure way, we have to concentrate with various security issues which has discussed in next section.

2.5. Security issues

With the commencement of cloud computing technology, it has also given so many issues in security and privacy issues. A number of security threats are associated with cloud data services: not only traditional security threats, such as network eavesdropping, illegal invasion, and denial of service attacks, but also specific cloud computing threats, such as side channel attacks, vulnerabilities, and abuse of cloud services^{20,21}. Since fog is deemed as a non-trivial extension of cloud, some security and privacy issues in the context of cloud computing, can be foreseen to unavoidably impact fog computing. Security and privacy issues will lag the promotion of fog computing if not well addressed, according to the fact that 74 percent of IT Executives and Chief Information Officers reject cloud in term of the risks in security and privacy. As fog computing is still in its initial stage, there is little work on security and privacy issues²². Since fog computing is proposed in the context of Internet of Things (IoT), and originated from cloud computing, security and privacy issues of cloud are inherited in fog computing²³. Client authentication, service security and database security are the prime concern in cloud computing environment. By keeping this on mind, it has been proposed a three tier security framework for sharing of health data across the web^{24,25,26}. From the above related work, it is summarized that, it requires a secure fog computing based framework for sharing and analysis of geospatial big data.

3. Proposed Model

3.1. Mist Computing

Mist computing has been taken from the edge and fog computing concepts further by pushing some of the computation to the edge of network, actuator devices and to the sensor which has built the whole network for cloud data center. With the help of mist computing the computation performed at the edge of network in the micro controllers of embedded nodes. Mist computing paradigm has decreased the latency and increased the autonomy of a solution²⁷. Cloud, Fog and Mist computing are complementary to each other w.r.t. the application tasks, which are more computationally intensive can be executed in the gateway of the fog layer while the less computationally intensive tasks can be executed in the edge devices. The processing and the collecting of data are still stored in the cloud data center for the availability to the user. The important application of mist computing is a collection of different services which has been distributed among the computing nodes²⁸. Both, fog computing and mist computing are coined by Cisco and located between the fog and the edge node, extend the classical client-server architecture to a more peer-to-peer based approach, similar or equal to edge²⁹. By considering this mist computing with security aspects, the proposed *SoA-Mist* framework sketched for processing of geospatial health big data analytics.

3.2. Prototype Development

For the prototype development of *SoA-Mist* i.e. Mist-based framework, the primary emphasis is on spiral model. In spiral model approach, the software development process adopts a sequence of steps including requirements pre-requisite plan, analysis, development strategy, operation and testing, complete module and framework observation. The process has incremental in nature and each implementation refines the analysis and developing stages through evaluation and testing of a completed module. So there are four phases in *SoA-Mist*. Phase I deals with the proposed model of *SoA-Mist* framework. Phase II describes about the use case and sequence diagram for proposed *SoA-Mist*. Phase III and Phase IV explain the overlay analysis of the geospatial data on mobile client environment in *SoA-Mist* framework and comparison analysis for Cloud framework and *SoA-Mist* framework. Figure 2 (a) shows the complete spiral model for development of *SoA-Mist*.

3.3. Proposed framework of *SoA-Mist*

This section describes various components of the proposed *SoA-Mist* framework and discusses the methods implemented in it. The main focus on *SoA-Mist* has been use of a practical approach to explore and extend the concept of security approaches for mist computing in geospatial health sector. It provides an efficient and effective means of sharing geospatial health data on the web. Figure 2 (b) has shown the proposed four-tier secure service oriented mist

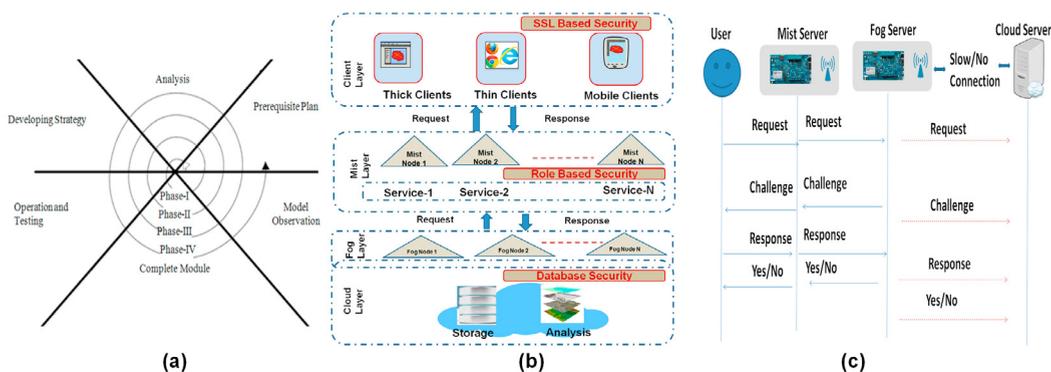


Fig. 2. (a) Spiral model for the development of SoA-Mist starting from requirement stage, analysis, designing, coding, testing and complete framework observation (b) Conceptual overview of SoA-Mist for enhanced security features (c) Sequence diagram of SoA-Mist Framework

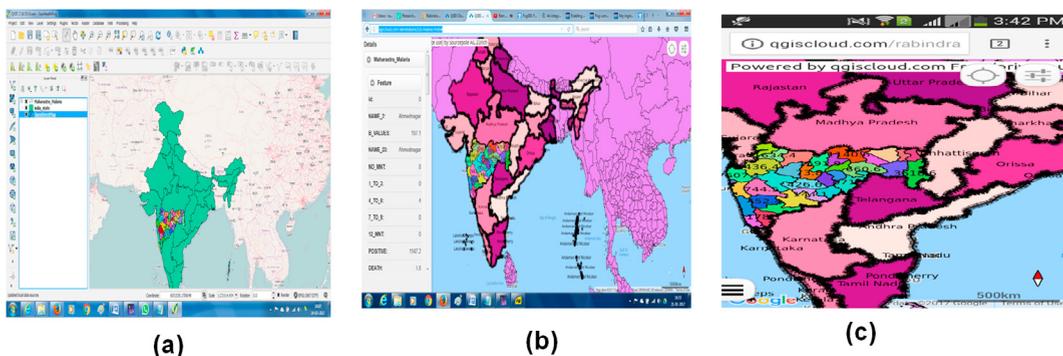


Fig. 3. (a) Integrated geospatial health database of Malaria in thick client environment (b) Overlay operation on thin client environment in qgis cloud³⁰ (c) Overlay operation on mobile client environment in QGIS cloud³¹

computing framework of geospatial health data resources. The basic over view of service provider, service consumer and catalog services are shown.

In the SoA-Mist framework, it is proposed to achieve the principle of CIA. Confidentiality can be achieved by SSL based security integration. Role based security is meant to focus on integrity of services whereas database security is to focus on the availability of data to the authenticated user. In the proposed SoA-Mist framework, it has proposed 3-tier security mechanism, the mist layer is technically meant to be role base access control mechanism. The easy to implement mechanisms like discretionary access control mechanism and mandatory access control mechanism can be used. Role base access control mechanism in a preventive way accesses the data tier and ultimately the data will reach the application layer passing through the security mechanism of the data tier and cloud layer. The user role is defined at the very beginning at the client layer by providing authorized access after authenticated verification of the user identity. In addition, it is expected that each phase would reveal a unique features related to the requirements of infrastructure and enable exploration of the interfaces between fog framework components. The requirements stage of application design aims to specify the behavior of the framework from perspective of a user. From the above defined SoA-Mist framework, it is described sequence diagram. Figure 2 (c) has illustrated the best possible sequence digram of SoA-Mist framework. In the proposed SoA-Mist framework, it is more secure for sharing of geospatial health data than cloud based framework. So the next result and discussions section describes about the overlay analysis and the comparison analysis of existing cloud framework with SoA-Mist by taking suitable parameters.

Table 1. Comparison analysis of cloud framework and *SoA-Mist* Framework

Features	Cloud Framework	<i>SoA-Mist</i>
Bandwidth Requirements and Internet Connectivity	Requires clients to have network connectivity to the cloud server and bandwidth requirements grow with the total amount of health data generated by clients.	Operates autonomously to provide uninterrupted services even no or intermittent Internet connectivity and network bandwidth requirements grow with total the amount of geospatial data that need to be process and sent to the cloud server after being authenticated by the mist layer.
Size	Processing has done with large amount of geospatial health data at a time and each typically contains tens of thousands of integrated servers	Mist node in each location can be small and work with role based access mechanism.
Server Locations	Requires centralized server in a small number of big data centers distributed environment	Requires distributed servers in many locations and over large geographical areas, closer to users along with mist-fog-cloud range

4. Results & Discussions

4.1. Overlay analysis in *SoA-Mist*

Here, geospatial overlay analysis has performed/processed for malaria vector borne disease positive maps of Maharashtra, India. It observed that two number of shape files related to malaria information mapping are overlaying with Google satellite layer. In this paper, malaria death mapping data of Maharashtra from 2011-2014 are used and processed in *SoA-Mist*. The overlay analysis of raster and vector data particular area has performed with in thin, thick and mobile clients. Primarily, developed datasets opened with Quantum GIS; desktop based open source GIS analysis tools, and performed join operations in mobile client. In Quantum GIS, QGIS Cloud plug-in is installed. The QGIS cloud plug-in is used to store vector and raster data in cloud data server. After storing in cloud data server, it generated thin client and mobile clients link for visualization. Figure 3 shows the overlay analysis on thin, thick, and mobile client environment. It observes that the overlay analysis is one of the useful and robust technique for visualization of geospatial health data.

4.2. Comparison analysis Cloud and *SoA-Mist* framework

Both Cloud and *SoA-Mist* frameworks have specific meaning for a service range with in the cloud computing and client tiers which provide the mutual benefit to each other and interdependent services that leads to the greater storage control, capacity, and communication with in the specified range⁷. Table 1 outlines the comparison characteristics of cloud and *SoA-Mist* framework.

5. Conclusions

In this study, we proposed *SoA-Mist* framework for enhanced analysis of geospatial health data. Intel Edison was used as mist and fog computers in developed prototypes of proposed *SoA-Mist*. Mist and fog devices reduced the storage requirements, transmission power leading to overall efficiency. It enhances the data analysis by increasing the throughput and reducing the latency. Geospatial health data of malaria vector borne disease positive maps of Maharashtra state in India has used as a case study. We performed the overlay analysis in thick, thin and mobile client environment for proposed *SoA-Mist* framework. Further, the comparison of computation between cloud and *SoA-Mist* has outlined. It has shown that the efficacy of proposed *SoA-Mist* framework over cloud and fog computing for enhanced analysis of geospatial health data. Thus, the mist and fog devices has added the more edge intelligence in geospatial health big data analytics.

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