Ambient Assisted Healthcare systems with fog computing

Prof. Vivek P. Dave[1], Dr. Narayan A. Joshi [2]
[1] Department of MCA, Faculty of IT & Computer Science, Parul University
[2] Department of MCA, Dharmsinh Desai University
(E-mail: vivekpdave.pietmca@gmail.com)

Abstract— Recent trends in research & development are highly focused on building smart support systems for healthcare. Objective is to provide technology-assisted solutions at home environment to reduce dependency of users on external entities. Emergency health services are developed for patients suffering from critical diseases in their surroundings. Ambient Assisted Living (AAL) systems are developed to provide self-care support to people suffering with physical or mental weakness. Modern technologies like cloud computing, edge computing, Fog computing is playing crucial role in development of AAL systems. In this paper, existing AAL systems with fog computing techniques in healthcare domain are reviewed comprehensively. Comparative study has been carried out on fog computing methods used in healthcare domain nowadays. Observations from our study are discussed in this paper.

Keywords— *Fog Computing, Cloud Computing, Ambient Assisted Living, Smart Healthcare, Monitoring, Mobility Tracking*

I. INTRODUCTION

Research and development in technologies like cloud computing, distributed computing and edge computing helps stakeholders to build smart & supportive environment for people. Healthcare domain is immensely benefitted through these technologies. Emergency health services are developed with cloud computing in recent past. Cloud computing can perform health related services more efficiently and remotely with pool of high-end resources and infrastructure at Cloud layer [1].

Evolution of intelligent devices and immense growth in smart healthcare demands formed some challenges for cloud computing based systems. Use of cloud computing for health emergency systems may generate some issues like:

a) High latency: Processes running outside edge network in cloud requires more processing time. Higher response may affect performance of healthcare services at time of emergency.

b) High computational power: Resources placed away from end users in cloud consumes more computational power.

c) High-risk of data privacy violation: Storing patient information at centralized data storage may cause privacy breach.

d) High Failover time: Recovery of cloud services required more time in case of major block or failure. It may affect continuous access of resources & services.

Fog can play a critical role to extend cloud by shifting intelligence and processing near to the user. Emergency support systems in health domain require techniques with minimal latency, localized data processing and reduced network bottlenecks. Fog computing approach can provide extended & optimized services in comparison with conventional cloud computing approach [8].

The remainder of the paper is organized as follows. In Section II, brief overview on fog computing & fog computing components is given. Section III includes review of literatures based on the related research work in identified domain. Discussion on scope and compatibility of fog computing for AAL-health emergency applications is represented in section IV followed by the conclusive remarks in section V.

II. FOG COMPUTING

The Fog computing term referred as an extension of cloud computing services from the centralized environment to the edge [19].

Cisco [16], defined fog computing as a system-level horizontal architecture that distributes resources and services of computing, storage, control and networking anywhere along the continuum from Cloud to Things.

National Institute of Standards and Technology [19], defined fog computing as a layered model for enabling ubiquitous access to a shared continuum of scalable computing resources. The fog computing model facilitates the deployment of distributed and latency-sensitive applications where fog nodes resides between smart end-devices and centralized cloud services [17].

Nodes with storage, computation and networking abilities can become fog nodes. Fog nodes can be deployed physical or virtually anywhere between cloud and end-users. Fog nodes can provide real-time processing, user control, minimum response time and transient storage. Fog nodes can send aggregated data periodically to Cloud [16].

In this paper, we have described the study on application of fog computing in the context of healthcare domain. The Fog platform can embed various *components* based on healthcare problem scenario. We studied core components in the context of healthcare domain and briefly discussed in this section:

a) Authentication & Authorization: Resources in fog computing are heterogeneous. Fog nodes need to authenticate & authorize each resource in order to provide accessibility [19].

b) Location Services: It is important to establish at least one fog node to track and share location of stationary or mobile end-users and connected fog nodes. Fog nodes maps location information received from different devices to the computing services [19].

c) Data Aggregation: In fog computing, data will be cleaned, analyzed & summarized by fog nodes to serve as base information to achieve specific objective. If required fog nodes can forward aggregated information to the cloud.

d) System Monitoring Service: System Monitor is one of the core component in cloud computing. Effective resource allocation and scheduling is possible with continuous observation on load and energy-consumption. Monitoring of fog computing system is essential.

e) Network Management: Network components are smarter and programmed in current times. Fog resources manages networking services near to edge and effectively provide node-to-node communication and software defined networking [20].

f) Offloading & provisioning Agent: Offloading agent transfers computational load to parallel or higher node to achieve processing balance. Provisioning of resources on demand can be performed by provisioning agent inside fog layer [21].

g) Virtualization Manager: Virtualization is one of the core component of fog computing. It allows to reduce dependency of resources on physical infrastructure. Running a fog instances over actual hardware using virtualization techniques provides way to create flexible computing environment. Policy of resource scheduling needs to be decided and provided to each virtual managers before running them in fog environment [19].

III. RELATED WORK

Yannis Nikoloudakis et al. in [1], developed an ambient intelligence system at home environment to support elderly people who needs continuous health observation. This system was developed for ageing people who are suffering with activity limitations. Their objective was to increase quality of life and to reduce health and social care costs for users. They used fog computing approach to provide monitoring and healthcare services. Fog computing techniques were used for alerting, positioning, profiling and networking. Orchestration layer was used at cloud layer to facilitate the seamless harvesting, managing, and provisioning of diverse distributed fog resources. Orchestrator instance was deployed using T-NOVA initiative to provide virtualized network functions for dynamic optimization of network & IT resources. To find available services on identified location and to map location information to service identifiers, they used Location-to-Service Translation (LoST) protocol. Mapped services was called using resource identifiers (URIs) to generate patient profile with location information. Selected patient profile was forwarded to external health agencies and to nearby volunteers.

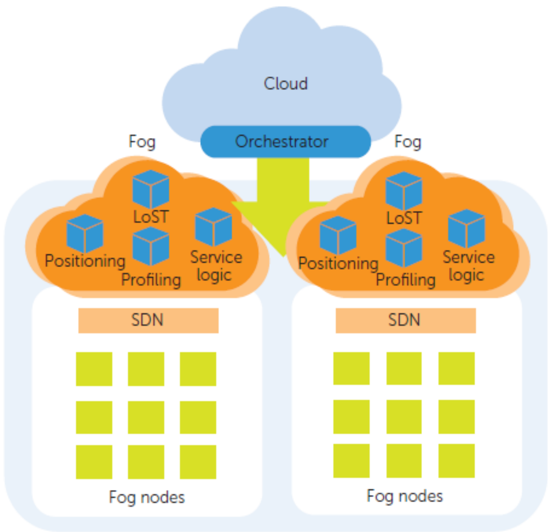

Fig. 1. System Architecture suggested in [1]

Jayneel Vora et al. in [2], developed a fog computing based support system for ambient assisted living for people suffering from neurological diseases. They have collected information of patient movement with implementation of motion sensors using body area networks. Clustering approach was used to provide efficient data acquisition. Collected data by sensors are transferred to cluster head to avoid delay in transfer in case of any anomaly detected in patient body. Cluster heads will forward data to fog node through edge gateway for processing. Fog node is given responsibility to make decision when to use priority gateway to initiated needed actions. Regression based analysis method was used to take appropriate decision. Priority gateway was used to alert health emergency services if required. Transient storage was provided in fog node during this decision process. Fig. 2 shows system architecture proposed in [2].

Octavian Fratu et al. in [3], developed a prototype monitoring system eWALL for monitoring patients who are suffering from Chronic Obstructive Pulmonary Disease and Mild Dementia. The eWALL prototype provides e-Health services and AAL at home environment with the help of fog computing. This prototype uses fog node for processing real-time health information and cloud node to store metadata of patient. The eWALL prototype uses sensors assembled on micro-controller board to collect patient information. In this prototype, analog gas sensors were used to detect smoke and flammable gasses. Fog node will notify patient about gas leakage or low oxygen level. Fog node was also given responsibility to alert health service providers about patient status.

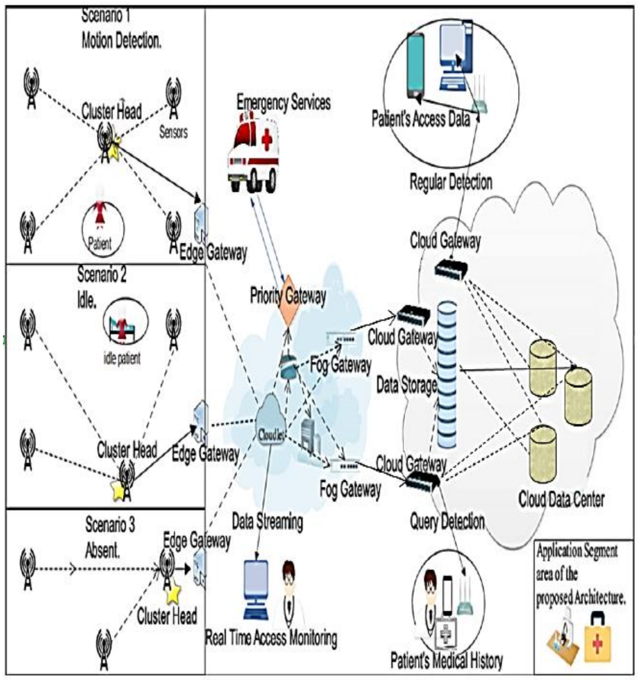

Fig. 2. System Architecture as suggested in [2]

K. Bhargava & Gary McManus in [4], suggested a design of low-cost wireless sensor based system for mobility monitoring and outdoor localization of Alzheimer's patients. They analyzed patient's behavioral aspects by collecting patient's routine activities and selected preferences. They have used fog computing technique to serve for real-time activity monitoring. Wearable device was designed and provided to patient. This wearable device acts as a fog node and collects activity information of patient when in use. Interactive Edge Mining (IEM) algorithm was used for real-time mobility tracking of user movement inside provided environment. With use of activity sequence generated by IEM algorithm and predefined topology information, patient location was estimated. Wearable activity tracker generates alerts upon detection of behavior anomalies. Fig. 3 represents state diagram for IEM analysis inside wearable device performed by authors in [4].

Eui-Nam Huh et al. in [5], developed a smart phone based service Emergency Help Alert Mobile Cloud (E-HAMC). They used fog-based services for location mapping

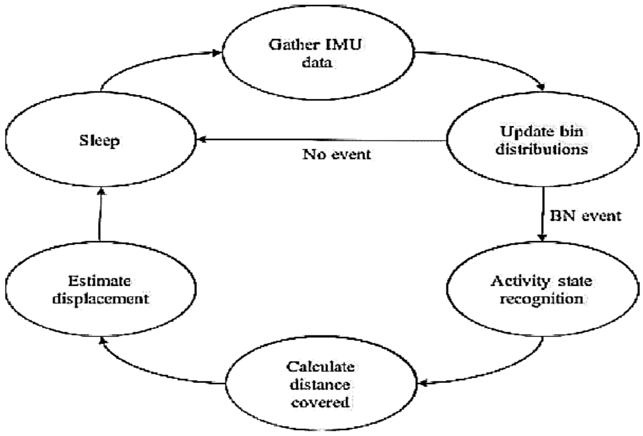

Fig. 3. State diagram of interactive edge mining performed inside wearable devices by authors of [4]

and alerting. Patient can use this system to alert relevant emergency dealing department and selected family members. Micro data center was implemented between user and using fog computing technique. E-HAMC system uses a smart gateway to forward incident information to fog-based micro data center or to cloud-based mega data center. Fig. 4 represents system architecture as suggested in [5].

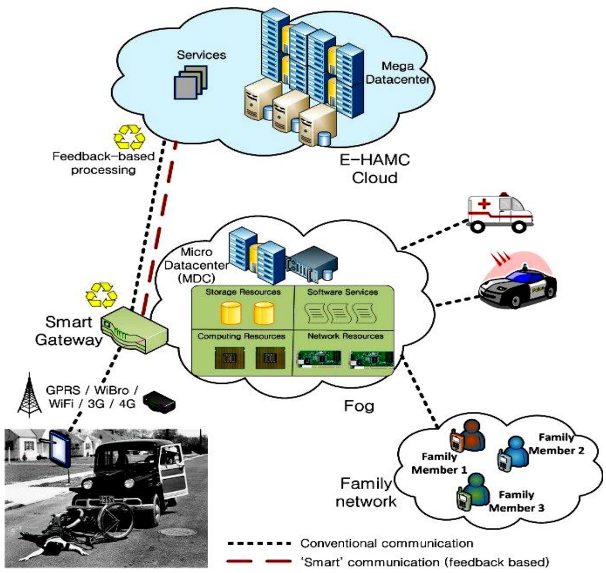

Fig. 4. E-HAMC System Architecture as in [5]

YingJuan Shi et al. [6], suggested a fog-based model for healthcare. In this model, they have deployed all devices and sensors in the local fog. This model uses fog node to perform filter, store and computer received data from sensors and devices. This model allows fog node to upload processes data to cloud for long time storage. In this model, fog node performs network switching to support multiple communication protocols. Fog computing approach was used in this model to resolve the latency issue caused by massive request flow from smart user devices.

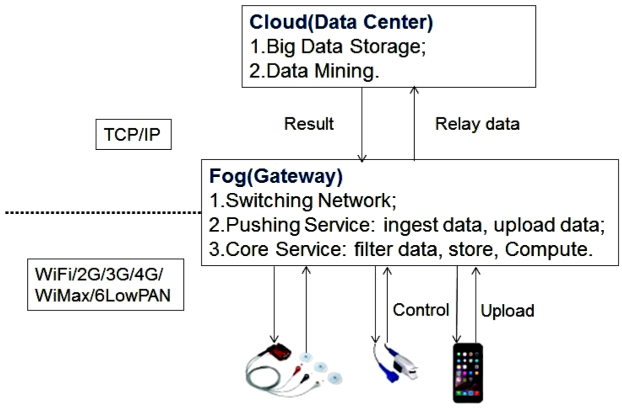

Fig. 5. Fog computing based services as suggested in [6]

Prabal Verma et al. [7], developed fog computing based patient monitoring system to provide intensive care at their home environment. Fog computing techniques is used by them for real-time health monitoring service. In this model, they used layered approach as represented in Table-I.

TABLE I: LAYERED APPROACH USED IN [7]

Layer No	Layer	Requisite functions/Components	Designated For
1	Cloud Storage Layer (CSL)	Daily Patient Information Storage	Health Service Providers
2	Decision Making Layer (DML)	Event based alert generating mechanism	
3	Information Mining Layer (IML)	Temporal Mining	
4	Event Classification Layer (ECL)	Event Classification Degree of Impact Layer Fog Layer	Responders
5	Data Acquisition Layer (DAL)	- Bio-Sensors - Smart Sensors - Smart Devices - Smart Phone - RFIDs	Patients

In this model [7], fog layer is used at a gateway to classify patient health state as safe or unsafe. When patient state goes unsafe, event will be triggered by fog-based services. On event triggering, fog node transfers patient's health information to cloud layer. Patient's health index is calculated at cloud layer to define urgency level of the situation. In this model, medical emergency service providers are connected to cloud layer. Cloud performs decision making based on health index and delivers patient information to medical emergency service provider.

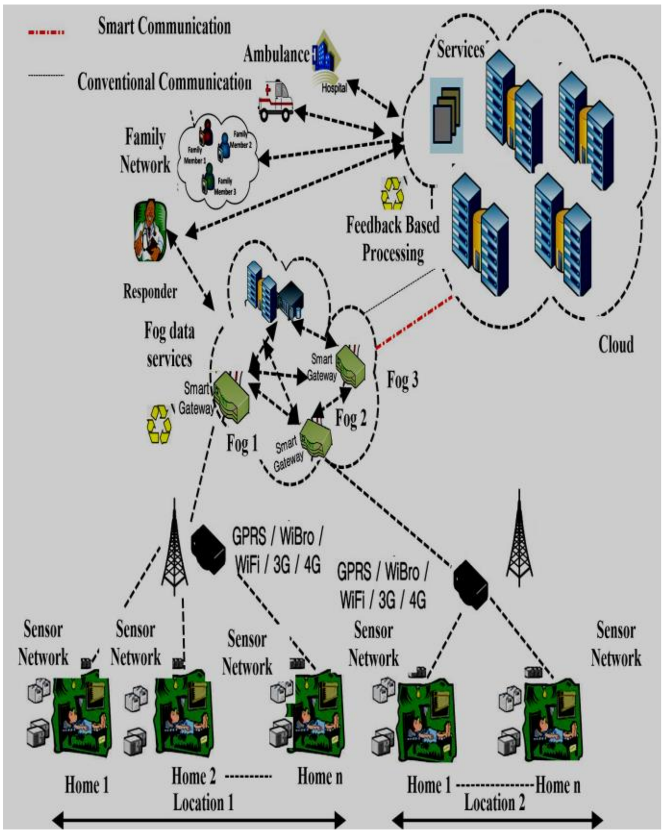

Fig. 6. Fog-assisted patient monitoring in smart homes as developed in [7]

IV. OBSERVATIONS

From study, we have observed that with fog-assisted AAL systems, intensive healthcare can be provided to people in their familiar environment. People who are suffering with critical disease can be benefited by providing healthcare support in their surroundings. With use of fog computing techniques, smart healthcare services can be provided as a part of ambient assisted living systems. We have performed comprehensive survey of fog-assisted AAL systems developed by researchers for healthcare.

Table II shows relative comparison of fog computing and cloud computing in context of ambient assisted living systems in healthcare domain. We have observed differences on the bases of requisite characteristics and functions. From our study, these characteristics and functions are identified as essential requirements to develop healthcare services for AAL systems. Table II clearly suggests that fog computing techniques are comparatively more feasible and efficient to satisfy essential requirements for ambient assisted systems for healthcare emergencies.

TABLE II. IMPACT OF FOG & CLOUD COMPUTING IN DEVELOPMENT OF HEALTHCARE EMERGENCY SYSTEMS

Base	**Services/ Components for AAL-Health systems**	**Fog computing platform**	**Cloud computing platform**
Requisite Functions for AAL	*Data Acquisition*	Local	Remote
	Data Computation	Near Edge	At Server located away from data source
	Monitoring	Short distance. Direct	Long distance. Indirect
	Prediction, Detection & Prevention	Fast	Slow
	Alerting	Fast & Wide-Spread	Slow & pre-defined
	Positioning	Fast	Slow
	Profiling	Inside Edge	Outside Edge
System Characteristics needed for efficient AAL Systems	*User Control and Involvement*	High	Low
	Possibility of Recovery in failure	High	Low
	Latency	Low	High
	Resource Availability in local environment	High	Low
	Environment Setup	Outdoors (Ambulances, Patient Home, Offices etc.)	Indoors (Data Centers or servers with large storage inside hospitals, medical centers etc.)
	Internode communication	High	Low
	Data Privacy	High	Low

A. Efficiency of fog computing approach in performing Requisite Functions for AAL:

a) Localized Data Acquisition: Data can be sensed and collected in local environment using the fog while the cloud is located away from end-user environment. Cloud approach requires greater effort and energy in sensing & collection of data.

b) In-Edge Data Computation: Computation load can be reduced by processing data in local environment with implementation of fog nodes.

c) Monitoring: Continuous monitoring of patient's activity is possible through implementation of sensor network and fog nodes. Fog nodes can analyze patient data received by sensors which are implemented in patient's surroundings. Examples of sensor networks are Body Area Network and Wireless Ad-hoc Sensor Network. Fog computing can support these kind of multiple sensor network and sensor devices to perform intense monitoring.

d) Quick Prediction, Detection & Prevention: Health status of targeted patients can be predicted or detected by performing analysis inside fog node. Severity of health emergency situation can be reduced with implementation of preventive methods at fog layer. From our study, it is observed that fog computing technique helps to build auto-responsive healthcare systems. Fog-assisted system can reduce need of manual diagnoses to minimize delay in treatment.

e) Wide-spread Alerting: Fog-based systems allow to create alarming mechanisms for health emergency situations. Medical emergency service provides can be alerted using fog-assisted communication techniques.

f) Quick Positioning: When patient status is declared unsafe by AAL systems, fog nodes can identify location of unsafe patient using fog computing techniques. Positioning service is an essential component of fog-assisted healthcare service. Location information can be mapped by fog nodes in required format. Precise location information can be shared to cloud.

g) Profiling from inside edge network: In health emergency, it is crucial to share patient profile to immediate responders within timeframe. Fog computing based profiling service can generate quick profile of patients in case of emergency.

B. Characteristics of Fog Computing needed for efficient AAL Systems:

a) Better User Control and Involvement*:* Controlled and Structured health services are possible to implement using layered fog implementation in extension to cloud.

b) High Possibility of Recovery in failure: Fast fail-over is needed for Health-AAL & recoverable services can be implemented through fog.

c) Reduced Latency: Fog computing techniques follows single hop approach for network requests against the multi-hop cloud network.

d) High Resource Availability in Local Environment: Resource allocation can be done with light-weight fog servers instead of high-end cloud servers

e) Indoor Environment Set-up: Smart Surroundings can be created as needed by smart assisted systems with Outdoor (Ambulances, Patient Home, Offices etc.) and Indoor (Data Centers or servers with large storage inside hospitals, medical centers etc.) implementation of fog components.

f) Internode Communication: Fog nodes can have inter-communication when needed to share data & services to extend support to requisite functions of AAL-Health Systems.

g) High Privacy of Critical Information: Secure Patient data inside edge network. Selected & encrypted data can be sent to Cloud.

V. CONCLUSION

In this paper, we have surveyed and discussed impact of fog computing technique in development of ambient assisted living systems for healthcare emergency. This paper also explains essential components of fog computing for AAL-Healthcare systems. Fog computing can provide ubiquitous and distributed services at local environment. The fog provides intensive healthcare services by extending cloud services near to user. This study suggests that fog computing can minimize overall load of cloud resources. On the basis of survey, we conclude that fog computing can improve the overall efficiency and performance of smart and ambient healthcare emergency services.

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