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# AN INVESTIGATION ON APPLICABILITY OF AD-HOC ROUTING PROTOCOLS IN FOG-ASSISTED SMART HEALTH CARE SYSTEM

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**ABSTRACT**

Cloud computing is widely adopted as it provides real-time services to users on a respectable scale in alignment with pay-per-use models. The heterogeneity and lively characteristics of the cloud network's components make failure inevitable. The failure also has an impact on the cloud service's dependability and accessibility. A computer paradigm called fog brings cloud computing services closer to edge hardware. Fog computing is being used more and more in applications that require faster real-time services, and the healthcare industry has embraced it heavily due to the urgent need to save lives. This work is aimed to investigate the suitable ad-hoc routing protocol for fog-assisted smart health monitoring system. By simulating with the network simulator NS-2 and using throughput, latency, and packet delivery ratio (PDR) as assessment criteria, the effectiveness of routing protocols is assessed. The protocols Ad-hoc on-demand Distance Vector (AODV), Destination Sequenced Distance Vector (DSDV), Dynamic Source Routing (DSR), and Optimized Link State Routing (OLSR) are being tested. The AODV exhibits encouraging results with other comparative protocols.

**Keywords:** adhoc networks, cloud computing, fog computing, healthcare, routing protocols.

## 1. INTRODUCTION

Although Cisco first used the term "fog" in 2012, it actually has origins in a concept called "cyber foraging," which was first described in 2001. In cyber foraging, mobile devices use high bandwidth networks with low latency to take advantage of a nearby server's capabilities. Fog similarly enables decentralized storage, analysis, and compute services for latency-sensitive applications. Similar emerging technologies, such as mobile edge computing and mobile cloud computing, are increasing network efficiency by utilizing cloud services on mobile devices [1, 2].

The fog node can be of five types namely servers, communication devices, vehicles, access points and cloudlets [1-3].

**Access Point:** In the wireless networking paradigm, access points are used to increase signal processing and achieve faultless communication. The biggest drawback of outfitting access points with storage and computing capabilities is that it also raises the deployment cost, resulting in small-sized cell access points.

**Cloudlets:** A cloudlet is accounted as a micro-cloud at the edge for centralized computing as opposed to fog.

**Communication Device:** The conventional networking equipments like switches, routers and gateways can be used as fog nodes accommodating processors with memory in it’s design.

**Server:** Fog node can be a server that is well suited for usage as a fog node and has fast storage and processing capabilities. However, the decision reduces the execution platform's ubiquity.

**Vehicles:** Based on their status, automobiles including cars, vans, and ambulances at the edge with processing capabilities can be set up as fog nodes (Idle or mobile). The difficulties in classifying moving objects as fog are fault tolerance and security.

As shown in Figure-1, the relationships between the fog nodes are constructed using the three available cooperation models [1, 3].

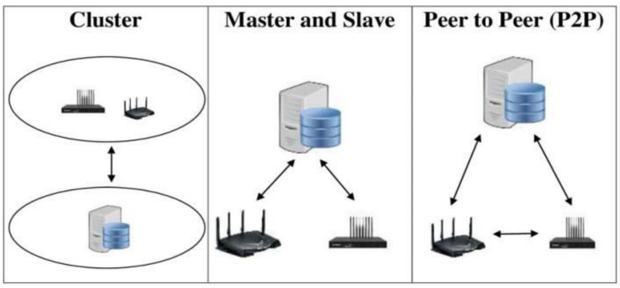


**Figure-1.** Prominent collaboration models of fog.

The following list and briefing include the most likely associations.

**Cluster:** The fog nodes cooperate with each other to provide services by grouping together depending on their

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proximity to one another or their shared characteristics. Dynamic formation causes load balancing problems among the available nodes, whereas static formation has scalability problems.

**Master-Slave:** One fog node is named as the master, while the others are named as slaves. In order to efficiently obtain the service, the master and it's slave worked together. For this collaboration model to operate smoothly, a large amount of network bandwidth is required.

**Peer to Peer (P2P):** P2P is the most popular approach for bringing cooperation among fog nodes, and it can be applied in either a hierarchical or flat fashion depending on proximity. Although it suggests reliability problems, it supports the reuse of nodes.

## 2. RELATED WORK

A thorough investigation was conducted to determine the value of fog computing in the healthcare industry. The article discussed the advantages of fog computing, the compute activities to be carried out, popular deployment sites, and implementation trade-offs [4]. In order to monitor chronic patients, a fog computing-based Internet of Things (IoT) application was constructed. The patient's end was equipped with wireless and wearable sensors to prevent unexpected attacks by continuously monitoring the patient's vital signs. The patient's extrinsic values were gathered using the environment sensors. Extrinsic values affect intrinsic health measures including blood pressure, heart rate, blood sugar, and so forth [5]. To manage the context-specific data coming from the edge, the fog computing layer is introduced. A thorough survey was carried out to determine whether fog may be used in Internet of Things applications. The article aims to cover the fundamentals of fog, including difficulties with clouds, how fog behaves when problems arise, and applications [6].

An innovative architecture for a remote health tracking system using big data analytics and the IoT was created. The authors suggested the Grouping and Choosing (GC) architecture and the Meta Fog Redirection (MFR) architecture as two huge data handling strategies. Here, the MFR is employed with a cloud like Apache H-Base and the GC architecture is used with a fog layer [7]. In order to guarantee data protection during transmission, this model is additionally equipped with security services. The effectiveness of this approach is demonstrated by a comparison with conventional algorithms. The model's drawback, however, is that it requires more computing time. Fog computing was used in the design of a smart remote health tracker to enhance the performance of the device. The important function of fog computing is discussed in detail. By giving instant time series data to mobile users who are all a little bit closer to the network, the deployment of a fog server reduces the demand for information and, as a result, increases the energy of the network [8].

To quickly handle the context-specific data from edge nodes, the fog computing layer is introduced. Applications used in healthcare must perform real-time processing as quickly as possible to generate faster replies. Fog was given two key responsibilities to do in this work: data analysis and data aggregation by distribution. Using the iFogSim toolbox, the system's effectiveness is assessed. Fog-cloud architecture was developed to create an intelligent healthcare system [9]. In that fog computing was used to address the IoT's dynamic requirements for low latency, security, and QoS. The purpose of the fog terminal was to carry out data collecting, aggregation, and real-time user interactions. The performance of the suggested work was presented through the simulation analysis.

A fog-assisted architecture was developed in order to monitor patient ECG data [3]. The data from IoT devices is intended to be filtered, prepared, and stored locally by the fog layer. The cloud-based preventive solutions were created with big data analytics. Through the use of IoT devices, Gill et al. offered a fog-enabled healthcare service. Fog was installed close to edge nodes and was thought to be an extended cloud, allowing it to consume large network capacity with low latency and produce user replies much more quickly [10]. With the aid of the simulation environment iFogSim, the performance was recorded.

Fog was outfitted with an artificial Intel Neural Compute Stick 2 (NCS2). Using deep learning techniques, this AI component was employed to automatically identify the ECG readings. Similar to the system designed to offer knowledgeable and effective healthcare solutions [11]. A concept of home hospitalization was created to safeguard elderly people with chronic illnesses. The concept was created with chronic patients from the current situation in mind (COVID-19 pandemic). The IoT, fog, and cloud computing are recognized as predominant technologies in achieving smart healthcare applications in realization [12]. While facilitating cost effective healthcare solutions to patients through sensors, one must focus on its energy factors too. The methodologies to preserve energy on sensor nodes are in demand [13].

The home hospitalization model monitors the patient and promptly notifies the doctor to begin treatment [14]. The user's mobile applications were used to initiate the required actions. Both doctors and patients largely agreed with the experimental examination of this approach. An electronic health application for remote pain treatment was realized [15]. Fog nodes were added to the application so that it could achieve latency-sensitive solutions. The simulation platform iFogSim was used to validate the results. In order to support latency-sensitive e-Healthcare applications, Shafiq *et al.* proposed an effective architecture for remote patient monitoring that included fog as a middle layer.

Modern developers are inspired by the layered architecture shown in Figure-2 and use it to apply to the IoT-based application [16]. Additionally, the majority of healthcare-based systems now in use recognized the fog as a middle layer.

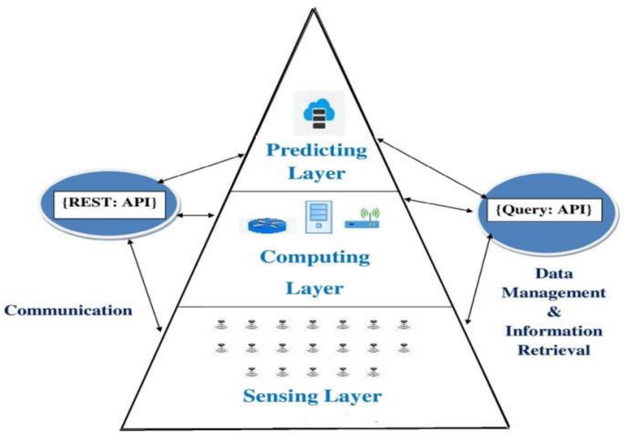


**Figure-2.** An architectural design of modern IoT solutions.

The IoT device at the very end frames the sensing layer, creates the raw data, and forms the device layer, also known as the IoT stratum. The fog stratum devices are designed to handle data pretreatment, modification, temporary storage, and basic analytical tasks over the data gathered from the IoT sensors. Fog is typically designed to do computationally expensive tasks. Long-term analytical operations, on the other hand, delve into multidimensional historical collections stored in the cloud to draw predictive information from them and make permanent storage available through the cloud stratum.

Representational State Transfer (REST) based API controls the communications between the stratums. It derives from the Internet of Things paradigm's request-response communication model. Among the available communication protocols, the IoT-based solutions that combine fog and cloud computing models pick REST HTTP as their primary choice [17]. The REST HTTP protocol is seen as being more reliable, mature, and requiring less training for developers to use. The performance analysis of AODV, DSR, DSDV and OLSR was carried out with help of NS2 simulator [18]. Furthermore, the suitability of above mentioned protocols in serving modern applications was examined [19-21] in facilitating effective system performance in terms of throughput, latency, and packet delivery. The query API is designed to extract helpful data from cloud strata, fog, or IoT sensors. The most popular protocols for connecting, communicating, and providing services for modern applications are listed in Table-1.

**Table-1.** Best practiced protocols for smart applications.

| Common Choice of Protocols | Operating Layer | Standard |
|---|---|---|
| Wi-Fi | Physical / Link | IEEE 802.11 |
| Zigbee | Physical / Link | IEEE 802.15.4 |
| Internet Protocol Version 6 (IPV6) | Network | IETF |
| IPv6 over Low -Power Wireless Personal Area Networks (6LOWPAN) | Network Adaption | IETF |
| Destination Sequenced Distance Vector(DSDV) | Network | - |
| Optimized Link State Routing(OLSR) | Network | RFC 3626 |
| Dynamic Source Routing (DSR) | Network | RFC 4728 |
| Adhoc On-demand Distance Vector (AODV) | Network | RFC 3561 |
| IPv6 Routing Protocol for Low-Power and Lossy Networks (RPL) | Network | RFC 6550 |
| REST Hypertext Transfer Protocol (REST HTTP) | Application | IETF |
| Constrained Application Protocol (CoAP) | Application | RFC 7252 |
| Message Queuing Telemetry Transport (MQTT) | Application | OASIS |
| Advanced Message Queuing Protocol (AMQP) | Application | OASIS |
| Data Distribution Service (DDS) | Application | OMG |

## 3. PROPOSED DESIGN

Remote patient monitoring (RPM) often keeps track of a patient's status on a regular or irregular basis, reports the information to its stakeholders, and makes an effort to forecast future conditions. The user's physiological state is collected via IoT devices. The cloud server processes and analyses the data to provide the response. The fog nodes are deployed between the edge and the cloud in this suggested strategy to address the problems. Figure-3 illustrates the structural components and services of a fog-assisted cloud for an IoT-based modern RPM.

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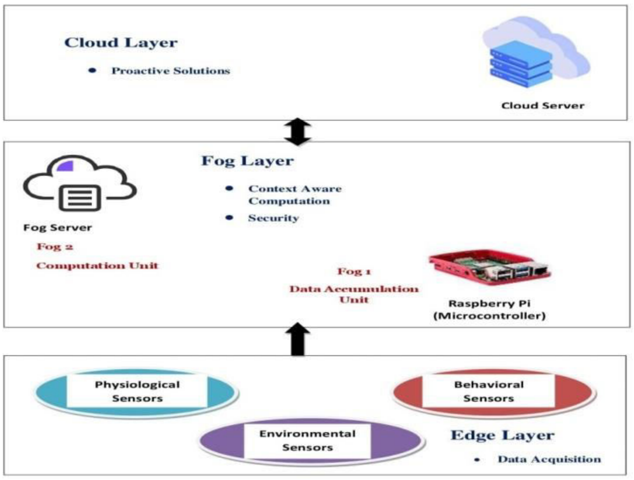


**Figure-3.** Components of fog-assisted modern RPM.

The fog layer is installed using the two fog nodes, the edge microcontroller, and the data server [22]. The major focus of the fog layer is to measure a person's health. The person's health condition is assessed as safe through thoughtful evaluation of Degree of Impact $D_{OI}$, signifying healthiness of them; there is no need to invoke emergent activities and further computation over cloud. The $D_{OI}$ calculation involves the physiological inputs with various influencing factors like environmental and behavioral factors of the patient. $D_{OI}$ is a probabilistic value that attempts to classify the state of the patient either as safe or unsafe based on the cumulative metric of contextual data being occurred in the time interval ($t_i$, $t_{i+k-1}$) where k denotes the total instances [23]. Thus the formula used to estimate the $D_{OI}$ is expressed as Equations (1) to (3) respectively.

$$D_{OI} = P(Safe)\ or\ P(Unsafe) \tag{1}$$

$$P(Safe) = \frac{No.\ of\ Safe\ Outcomes}{No.\ of\ Possible\ Outcomes} \tag{2}$$

$$P(Unsafe) = \frac{No.\ of\ Unsafe\ Outcomes}{No.\ of\ Possible\ Outcomes} \tag{3}$$

Upon the unsafe state of the patient, to predict the health aliments of the patient early and avoid critical circumstances, initially an alert is generated and communicated over the family and medical experts. The value of $D_{OI}$ facilitates an indication about deciding the time to transmit the data to the cloud. The preprocessing, rule generation and predicting the current state aligned with the rule are carried out by the fog server. The fog server is the second most fog node positioned between edge layer and cloud layer. The fog layer avoids transmission of all the data acquired from device layer, assessing the state of patient in fog, permits only the unsafe patient's data to cloud for further investigation. Thus the proposed design with fogging ensures utilization of high bandwidth and it is captured via throughput. It is evaluated by calculating the amount of data transferred via the fog device and arrived by the cloud server within a stipulated period of time. Here the data exhibited from the WBAN with environmental and behavioral context are transferred to cloud in the case of unsafe state of patient.

## 4. RESULTS AND DISCUSSIONS

This section is attempted to justify the benefits of fog computing and explore the usage of fog nodes to be used within the upcoming pervasive applications. The effective routing protocol fits for fog computing paradigm is also investigated.

### 4.1 Simulation Platform

To demonstrate the characteristics of fog, the NS-2 network simulator is employed. In the simulation environment, the function of routing as well as well-known protocols is examined. The analysis's simulation parameters are listed in Table-2 below.

**Table-2.** Simulation parametrs for performance analysis.

| Network Type | Mobile |
|---|---|
| Connection Pattern | Random |
| Packet Size | 512 bytes |
| Duration | 300s |
| Simulation area(sq. m) | 100*100 |
| Number of Nodes | 15, 25, 50, 75, 100,125,150,175,200 |
| Pause time | 1200 ms |
| Connection type | CBR/UDP |
| Energy Model | Battery |
| Routing Protocols | AODV, DSDV, DSR, OLSR |
| MAC Protocol | IEEE 802.11p |

Among the numerous sensor devices, two fog nodes and a cloud server are configured in accordance with the fog hierarchical deployment architecture from the Open Fog Reference Architecture to handle the suggested context aware RPM. Figure-4 depicts the suggested RPM arrangement in the NS-2 NAM timeframe.

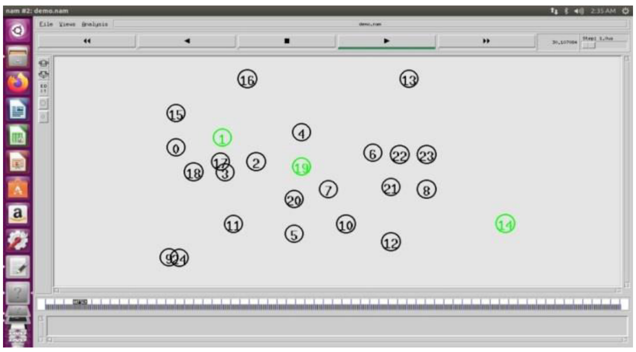

**Figure-4.** Fog-assisted modern RPM configuration.

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### 4.2 Assessment Criteria

The factors used to demonstrate the efficiency of fog as well effectiveness of routing protocols applicable to the same are listed below.

**End-to-End Delay (EED):** It is defined as the time taken to transmit the entire message from the source to destination and specified as Equation (4). It accounts the total time utilized from its initiation, transmission, queuing and attained delay in processing.

$$EED = PT + TT + QT + PD \tag{4}$$

**Packet Delivery Ratio (PDR):** It is the ratio between the total number of bits received at the destination and the total number of bits sent from the source, expressed as Equation (5).

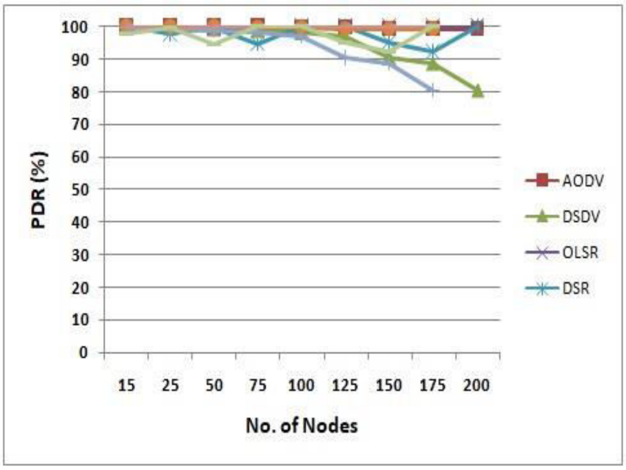
$$PDR = \frac{Total\ No.\ of\ \mathrm{Re}\,ceived}{Total\ No.\ of\ sent} \tag{5}$$

**Throughput:** It intimates the rate of successful data transmission per unit time normally in seconds. It evaluates the speed of the network over the channel of communication and formulated as Equation (6).

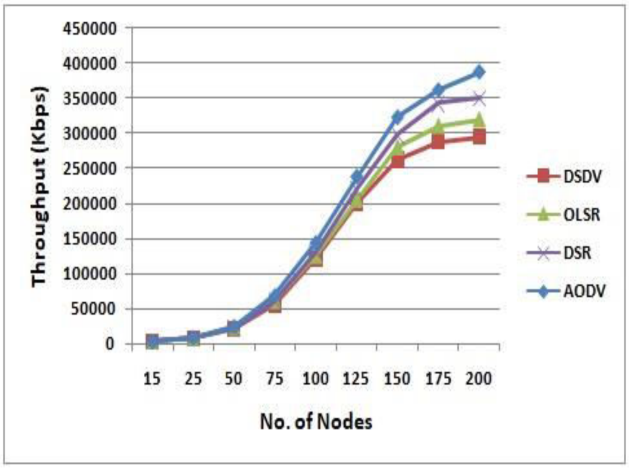
$$Throughput = \frac{Total\ No.\ of\ Data\ Successfully\ Transmitted}{Unit\ Time} \tag{6}$$

### 4.3 Evaluation Results

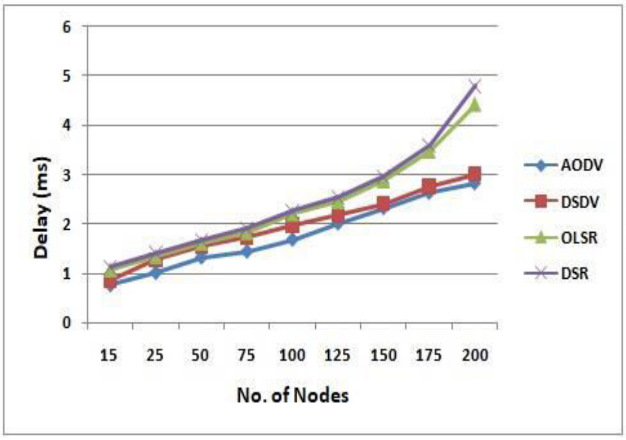
The comparative analysis of selected routing protocols based on it's performance factors listed in the above section is provided in Figure-5.




(a)




(b)




(c)

**Figure 5.** Performance analysis of routing protocols presenting a) based on PDR b) based on throughput c) Based on delay (EED)

Increasing the number of edge nodes or sensors usually causes lower PDR, lower throughput and higher delay. According to the analysis, AODV maintained a consistent higher PDR, higher throughput and lower delay comparable with other routing protocols. The performance of the protocol observed a little closer to AODV is DSR. With evaluated average throughput, AODV is observed 1.24% faster than DSDV, 1.17% than OLSR and 1.09% than DSR. Likely considering PDR, AODV provided highest ratio as with 1.05% than DSDV, 1% than OLSR and 1.02% than DSR. AODV facilitated less delay as 0.9% than DSDV, 0.76% than OLSR and 0.72% than DSR.

Aligned with the current scenario, reactive protocols exhibited better performance than the proactive category. To pinpoint the complete efficiency of fog based approach against the traditional one, the fog based scenario devised is evaluated with the system without using it. The efficiency plot presented in Figure 6 outbreaks the fact of using the fog in achieving greater transmission speed. The evaluation result encourages the adaptation of fog computing in recent applications without any doubt.

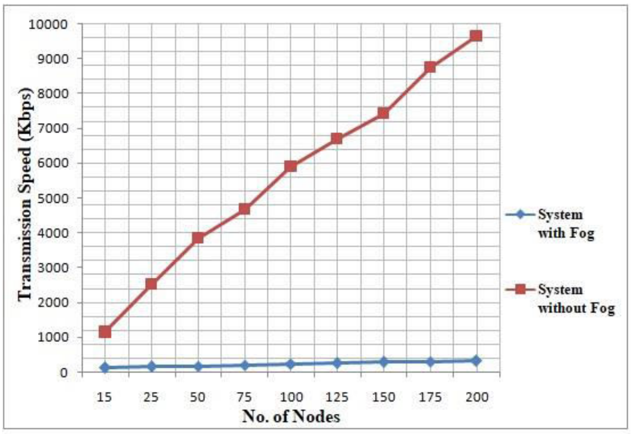



**Figure-6.** Comparative analysis of the system with fog vs. without fog.

## 5. CONCLUSIONS

Real-time interactions, minimal latency, and efficient network use are reported to be properties of fog that make it a great choice to incorporate into smart applications. The effectiveness of fogging is demonstrated using the network simulator NS-2. Further, a deep examination to identify the prospective routing protocol of choice which is appropriate for fog also conducted. The outcomes of the simulation encourage the use of AODV for efficient routing. The microcontroller and the proxy server are specifically chosen as the main operational components of the suggested fog layer. The microcontroller is in charge of data aggregation. While the service that determines a person's health status is run on a server to accommodate its computational complexity. In comparison to a standard cloud environment, the inclusion of fog into RPM design boosts transmission speed by 24.7 percent and application computing service by 3.46 percent.

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