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Simulation Result of Fog Computing Framework Using Fog Management Scheme

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Abstract: The edge of a corporate network is where fog computing is extended from the cloud. Fog computing, a promising paradigm for computing, enables network, storage, and computing services between terminals and cloud data centres. Large-scale IoT application deployment and cloud computing both gain from its many advantages, including low latency, data locality, location awareness, mobility, lower computational costs, and geographic distribution. The main objective of this study is to statistically and analytically classify current research methods related to security issues and solutions for fog computing that have been published between 2014 and 2021. Then, in response to the queries, a few technical queries in this area are given, along with the advantages and disadvantages of each suggested fog security approach and some suggestions for addressing security flaws in fog computing. For designing, implementing, and maintaining fog systems, some future motivational directions and open issues in this field are provided.

Keywords: **Fog Computing, Cloud Computing, IoT, Fog management scheme, Fog Workload**

I. Introduction

Cloud computing has grown in popularity in recent years due to its computing, data storage, and network management capabilities. All of these tasks are carried out in centralised data centres. It has gained popularity as a cost-effective service among individuals and organisations, and it is also in high demand in a variety of domains. As a result, global cloud computing scaling has become extremely effective. It is capable of delivering the appropriate amount of resources at the appropriate time and location. It also increased an organization's productivity by reducing the number of tasks that IT teams had to complete. These are the results of improved cloud computing performance, security, and dependability. Cloud computing services are classified into three types: infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS) (SaaS). However, cloud computing faces numerous challenges in the future. The number of Internet-connected devices has increased dramatically over the last few years.

As a result, there is a high demand for IoT all over the world. With billions of geographically dispersed IoT devices, these centralised cloud data centres frequently fail to function. This cloud computing framework is incapable of providing real-time services and frequently causes network congestion and high service latency. To meet all of these demands, Cisco introduced the concept of "Fog Computing." It is a cloud-based service extension that is much closer to the IoT nodes. This fog layer acts as a layer of protection between cloud data centres and end users. This layer has resulted in the decentralisation of data centres. Fog refers to the migration of the cloud to the network's edge, where end devices such as routers become virtualized. Fog computing has become an urgent requirement among individuals and organisations due to its numerous benefits. Real-time service support, low latency, location awareness, mobility support, geographic distribution, low power consumption, less network congestion, processing a large number of nodes, cost effectiveness, reliability, and so on are some of them.

Fog Computing is defined as a highly virtualised platform that provides similar cloud facilities in terms of storage, processing, and communications, but closer to things than the cloud; i.e., between things and clouds [18], with the goal of enabling fast, secure, and reliable services. [19, 16]. Fog is not a replacement for cloud, but rather a complement to it, because both are expected to work together [1]. In general, fog can support, serve, and facilitate services that the cloud cannot, such as I latency-sensitive services (e.g., healthcare monitoring and online gaming) [14], II geo-distributed services (e.g., pipeline monitoring) [22], III mobile services with high speed connectivity (e.g., connected vehicles) [3], and IV large scale distributed control systems (e.g., smart energy distribution and smart traffic lights).

Fog-based services are generally owned by different parties in fog computing for a variety of reasons:
(i) The deployment option, which may include choosing between Internet service providers or wireless carriers.
(ii) Companies extending their existing cloud-based services to the edge to improve performance, and
(iii) Companies that lease excess resources on the local private cloud as fog services. [23].

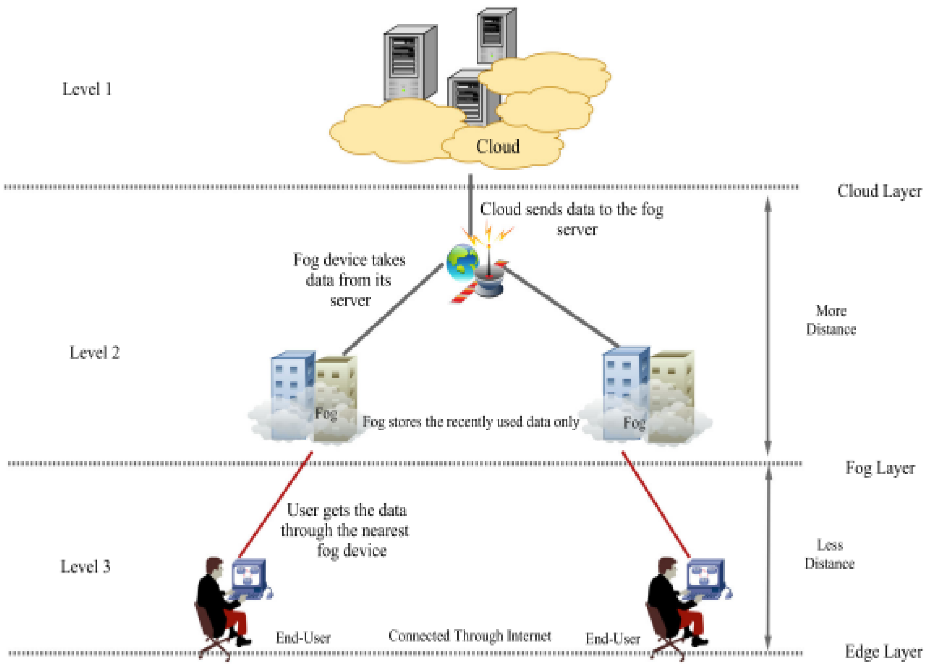


Fig.1Typical cloud-fog computing architecture

II. Cloud Computing

The cloud computing paradigm is a well-studied centralised computing paradigm that emphasises the dynamic provisioning of computational and storage resources. These assets are kept in centralised data centres. As a result, a variety of factors, such as ambient energy costs, temperature, and land prices, influence the location of the DC. Cloud providers offer resources such as software services that can be accessed through a web browser, developer platforms for creating and deploying cloud applications, and complete server infrastructures for managing Virtual Machines (VMs) that run on cloud resources.

Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), and Infrastructure-as-a-Service (IaaS) are the three cloud resource delivery service models (IaaS). Aside from these different service models, four distinct cloud deployment models have emerged: I private cloud, II community cloud, III public cloud, and IV hybrid cloud. The specifics of these deployment models are presented. Cloud providers use the aforementioned Virtualization technology to dynamically provision massive amounts of on-demand resources on a pay-per-use basis. The following is the NIST definition of cloud computing. The definition includes characteristics, service models, and deployment models.

According to the National Institute of Standards and Technology, cloud computing is "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (NIST). Cloud computing combines existing technologies such as virtualization, grid computing, and utility-based pricing to meet industrial demands. There are five distinct characteristics of the cloud, three distinct service models, and four distinct deployment models.

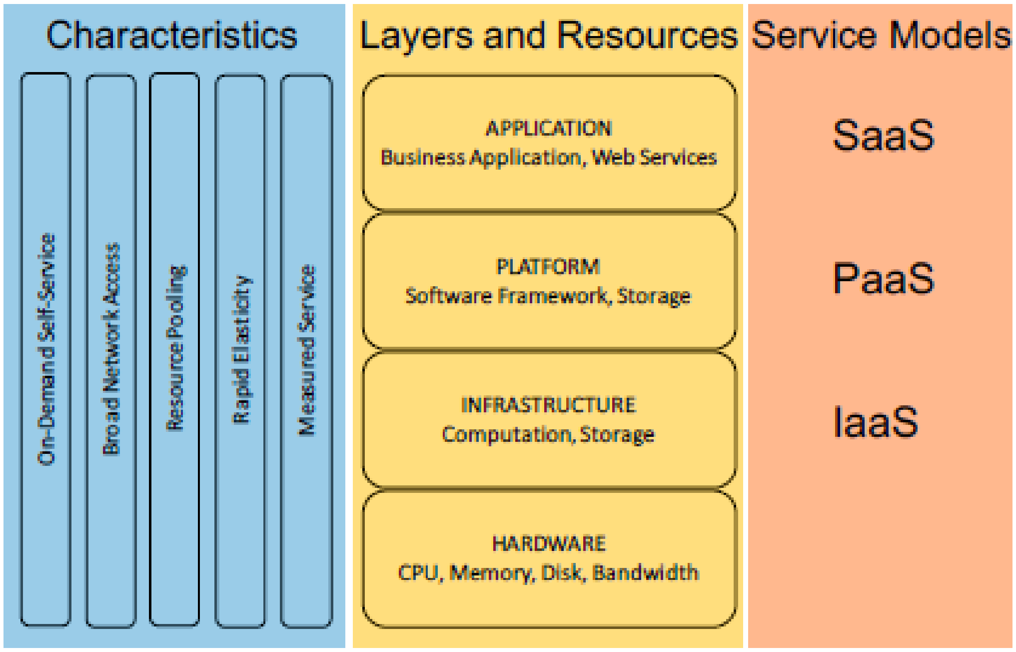


Fig.2 Cloud Computing Overview

- **On-demand self-service:** a consumer can provision computing services on their own that may require server time and network storage. Without requiring any human interaction with the service provider.
- **Network access:** services and capabilities are made available through standard mechanisms that encourage and permit the use of diverse client platforms.
- **Resource pooling:** Using a multi-tenant model with different physical and virtual resources dynamically assigned and reassigned based on consumer demand, the provider's computing and storage resources are combined to allow services to be used by multiple consumers. In terms of location, the consumer frequently has no knowledge or control over the location of the provided resources, but itmay be able to specify location at a higher level of abstraction.
- **Measured service:** Cloud systems control and optimize resource use automatically by leveraging metering capabilities at some level of abstraction appropriate to the type of service (e.g., storage, processing and bandwidth). The use of resources can be tracked, controlled, and reported on. As a result, transparency is provided for both the service provider and the service consumer.

III. Fog Resource management Scheme

Although fog nodes are placed closer to IoT devices to reduce latency, if the number of requests for their services exceeds their capabilities, these nodes can quickly become congested [14]. [3]. In the IoT architecture, the fog layer is made up of heterogeneous devices that are clustered together to form "fog domains." Each fog device/node has its own coverage range within which it delivers the desired fog services. Indeed, due to node heterogeneity, service types and sizes (for example, processing speed and storage capacity) differ from one fog node to the next, making it unclear how fog services are managed and delivered. Many questions arise, including how to provide fog's services. "and who manages and monitors fog resource consumption and provisioning?" to evaluate the QoS and performance of the fog devices. This entire gap is proposed to be filled by the Fog Resource Management Scheme (FRAMES). This section goes over FRAMES, which is in charge of managing the status of fog resources as well as providing network analysis and statistics for fog resource provisioning and consumption. The FRAMES conceptual diagram is shown in Figure 3. The primary function is to regularly monitor the status of fogs and network loads.

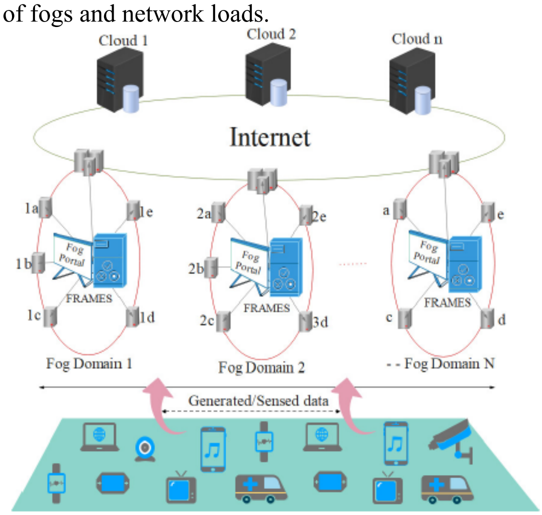


Fig. 3: Overview of the Fog Resource manAgeMEnt Scheme

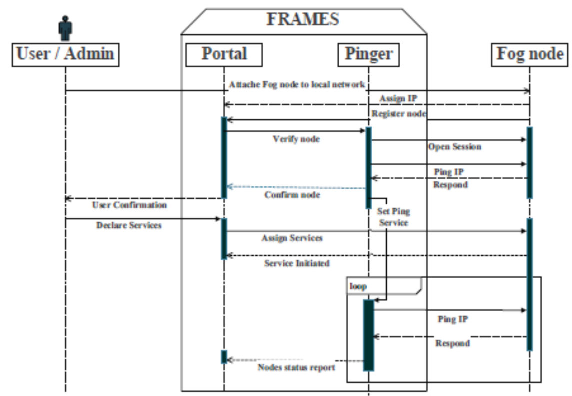


Fig. 4: Sequence diagram showing FRAMES interactions

IV. Fog-2-Fog Coordination Model

This section discusses the network model that enables face-to-face coordination. It also discusses potential sources of delay that may have an impact on this coordination.

IV.1 Network Model

In the context of F2F coordination, communication among fog nodes is modelled as an undirected graph, so that all fog nodes can be reached by each other. With G = hN; L;Wi, where N is a set of thing, fog, and cloud nodes, G = NI [NF [NC]. The letter L represents the set of communication links that connect all nodes across the things, fog, and cloud layers. While the notation W represents the set of edge weights between nodes based on their distance, the longer the distance, the higher the weight. Thus, the propagation delay Dp is affected by the edge weight between two nodes.

IV.2 Service Delay

A service request is a collection of tasks that must be completed in order to meet the requirements of the desired service. A service request can be processed through any of the three layers (i.e., thing, fog, and cloud). Following that, FRAMES computes the total time required to process a service. The expresses the service delay (Sd) for a tn request:

$$S_d = \rho_i^F * [D_t^F + D_p^F + D_c^F]$$
$$+ \rho_i^C * [D_t^C + D_p^C + D_c^C]$$

IV.3 Delay Sources

These delay sources can have a significant impact on service performance and meeting deadlines, resulting in latency. To calculate the delay correctly, it is necessary to understand where the service will be processed and what parameters will be involved in the processing. As a result, FRAMES focuses on minimising service processing latency over the fog layer via F2F coordination, resulting in minimal service transmission delay (Dt), propagation delay (Dp), and computational delay (Dc), which includes both queuing delay (Dque) and processing delay (Dc) (Dproc).

IV.4 Transmission Delay

Transmission Delay (Dt) is the amount of time it takes a sender (i.e., thing) to send data packets over a network. To calculate the transmission time required by a specific thing, it must first determine the packet size or packet length lp in bits and the data rate (i.e., upload bandwidth) b↑

$$D_t = \frac{l_p}{b \upharpoonleft\uparrow}$$

$$D_t^n = \sum \frac{l_p^n}{b \uparrow}$$

IV.5 Propagation Delay

The time required to transmit all data packets over a physical link from source (e.g., thing) to destination is referred to as propagation delay (Dp) (e.g., fog). The delay will be calculated using the physical link length ld and propagation speed ps. The length can be calculated using the thing's latitude and longitude as well as fog.

$$D_p^n = \frac{l_d^n}{p_s}$$

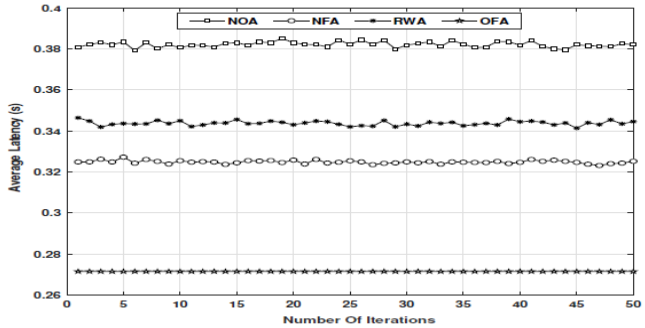
IV.6 Computational Delay

The total time taken by fi to compute a service requested by tn is referred to as computational delay (Dc). This time includes both queuing and processing delays (Dproc). The Dque is the amount of time a data packet spends inside a fog node's queue/buffer before being served. The Dproc, on the other hand, is the time taken by the fog node to process the received data/packet (s). The Dc will provide the actual time required to process the service request based on the fog node's capability and current load.

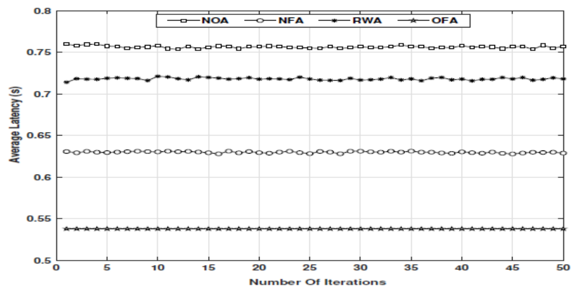
$$D_{proc}^s = max_{q \to Q_s}(\sum_{t \in Q_s^q} d_{f_i^c}^{ts}), \forall q \in Q, \forall c \in C$$

V. Results

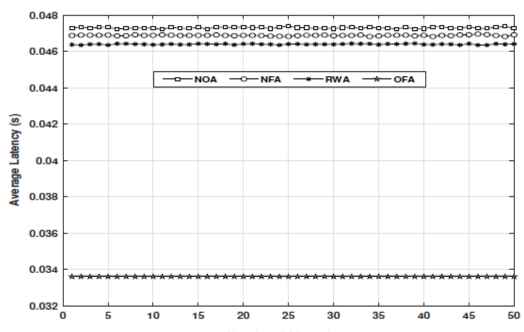
This section describes the MATLAB simulation settings used, as well as the setup parameters. According to the proposed model, the configuration settings specify the network topology, propagation and transmission delay, link bandwidth, and fog node capabilities.



(a) Mixed types of packets (MTP)



(b) All heavy packets (AHP)



(c) All light packets (ALP)

Fig. 5: Average latency according to offloading model

Figure 5 depicts our OFA's performance based on the average response time for all received service requests classified by packet type. It also provides a comparison of the results of OFA and the results of other algorithms.

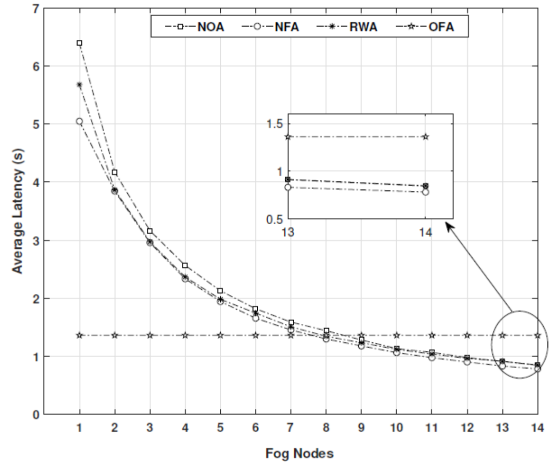


Fig.6 Average latency per node

OFA clearly achieves a consistent average latency. As a result, work assigned to fog nodes takes into account overall capacity and current load before offloading a request, whereas NFA and RWA are relatively blind in this regard. As a result, OFA achieves nearly consistent latency on each individual node, whereas NFA and RWA average latency varies and is inconsistent.

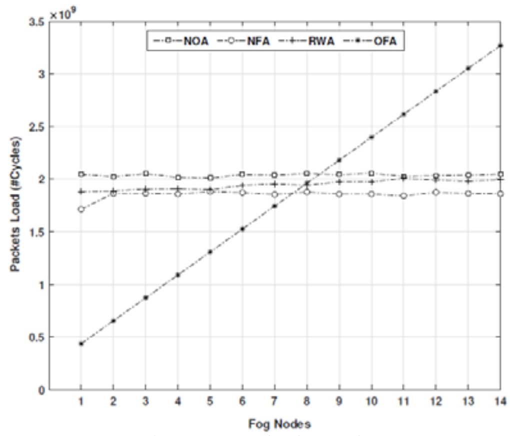
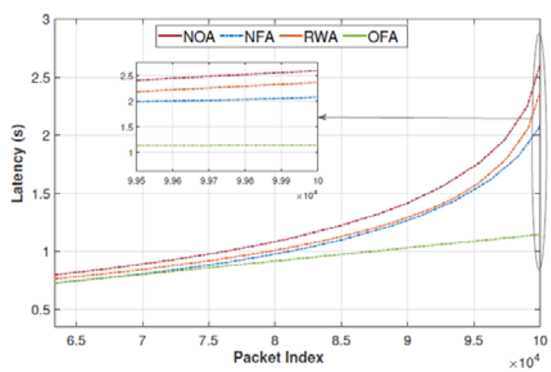
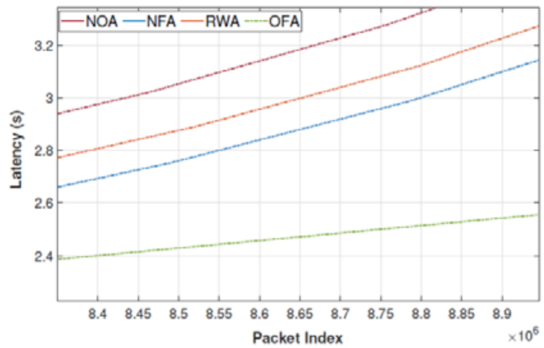


Fig.7: Average load on nodes

To demonstrate the optimal packet distribution with OFA, and run a new experiment and reuse the settings from the previous experiment. In this experiment, however, the vertical line represents service usage (i.e., the number of packets).



(a) Packet index upto 10^4



(b) Packet index upto 10^6 to show the variations

Fig.8: Latency per packet

The effect of increasing the number of packets on latency is depicted in Figure 8. In Figure 8a, the service's packets are varied from one to 10x104 during simulation; thus, the packet type is fixed to heavy-packet for consistency. The service utilisation rate is an incremental parameter ranging from 1% to 100%; thus, this rate is constant at any given timestamp. For example, if the service utilisation rate is 50%, all algorithms; OFA, NAF, RWA, and NOA will receive the same rate.

The maximum latency for an OFA packet is around 1:2 second, and the maximum latency in Figure 9 is 0:8 second. In both cases, it is clear that OFA outperforms NFA and RWA in terms of response time.

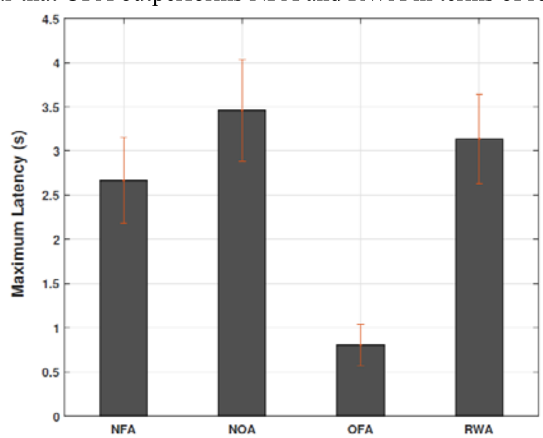


Fig.9: Maximum latency upon heavy-packets

VI. Conclusion

The research focuses on the utility and management of fog computing. Despite the fact that fog computing is recognised as a computing model that is appropriate for IoT systems/applications, it is not widely used due to the spatial and temporal dynamics of IoT thing distribution, which makes fog node management and distribution difficult. This may also cause significant variation in the computation loads on fogs. As a result, while some fog nodes may be lightly loaded, others may not be, resulting in fog congestion and latency. The proposed OFA has the shortest service response time when compared to RWA and NFA. Furthermore, based on their capabilities, OFA outperformed RWA and NFA not only in latency but also in service packet distribution over fog nodes. Offloading is generally unnecessary when all fog nodes have low loads, and it will not help to reduce delay when all fog nodes have heavy loads. Offloading is only useful when the fog nodes are highly variable. In order to highlight the importance and benefits of implementing the fog computing paradigm, OFA has the potential to achieve a sustainable network paradigm.

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