Scalable Hotspot Infrastructure Using Fog Layer Decentralization Mechanism

NWABUEZE, C. A.[1], AKANEME, S. A.[2], ANYANWU, S. C.[3]
[1, 2, 3] *Department of Electrical/Electronic Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli Anambra State, Nigeria.*

Abstract- Hotspot is an interface where one can access the internet using a wifi, via a WLAN (Wireless Local Area Network). In existing hotspot networks, the equipment for service delivery complies with the Institute of Electrical and Electronic Engineers (IEEE) 802.11 standard but not efficient for enterprise workload environment. For these testbeds, 3G/4G wireless-N Router (TL-MR3420), Wireless-N-300Mbps outdoor Access point (ENS202EXT), dual band long range wireless-N900 outdoor access point (ENH900EXT), Microtik Router Board 1100 X2AH, etc are normally used. The era of cloud and fog computing cannot thrive with the legacy IEEE 802.11 variants. This work proposes a scalable hotspot network that uses fog layer decentralization mechanism (FLDM) for better Quality of Service (QoS).Mathematical characterization of the fog decentralization layer for scalability and redundant duplication was formulated. From the system design/fog edge hotspot network (FEHN), three evaluations were carried out in terms of data packet delay, network utilization and capacity. A default hotspot network without Fog Layer and with Fog Layer was implemented. In the evaluation for resource utilization, complex and high degree of resource utilization in the default (Nnamdi Azikiwe University) was observed to be 0.0057(75%), while FEHN utilization was 0.003 (25%) which is ideal for high density network settings. In the evaluation for Network Latency (delay), with the default (Nnamdi Azikiwe University), the network delay is shown to be 0.0007secs (63.55%) while with the improved Fog FEHN, the network delay was observed to be 0.00038secs (36.45%). Furthermore, the effect on network load intensity showed that stable elasticity is reached at 2000bits/sec and 1900bits/sec respectively. The results show that a scalable hotspot infrastructure using Fog Layer Decentralization Mechanism will be optimal for large scale network services. With the implementation of fog layer decentralization on IEEE 802.11g/n hotspots, users can enjoy better and improved QoS and networks can be implemented on scalable platform for better service delivery.

Indexed Terms- FEHN, QoS, IEEE, NAU, FLDM.

I. INTRODUCTION

Fog computing is a term created by Cisco that refers to extending cloud computing to the edge of an enterprise's network. Currently, existing hotspot infrastructure provides flexible but inadequate method of communication and collaboration in a data intensive environment using the IEEE 802.11 standard AP (Access Point) [1].

These hotspot networks are found in most tertiary institutions today but are not efficient for enterprise workload environments where image data contents are paramount. In university settings, a typical campus network interconnects many departments across so many buildings, providing high speed access for both students and staff. Once connected, users have access to a wide range of resources such as printers, network file servers, research materials, lecture notes, tutorials, and lecture on demand [2]. Other services in such hotspots include streaming multimedia, peer to peer file sharing. Applications such as email, discussion forum, bulletin boards, class schedulers, resource booking systems and various administrative applications are also available through the campus network. A hotspot is an interface where one can access the internet using a Wi-Fi (Wireless-Fidelity) technology via a WLAN (Wireless Local Area Network)

[3] Presented issues in WLAN hotspots where collision avoidance protocol used by IEEE 802.11 wireless network to manage contention increases each individual client's time to access the network. Increase in the number of users lead to more delay, resulting in slower speeds for each user and even application timeout. Hence the proposed use of Fog layer computing in hotspot networks to offer new opportunities for network expansion – Fog layer

Decentralization. Fog computing also known as fog networking is a decentralized computing infrastructure in which data, computing, storage, control and applications are distributed in the most logical, efficient place between the data source and the cloud to offer better quality of service (QoS). This network consists of a control plane and a data plane. For example, on the data plane, fog computing enables computing services to reside at the edge of the network as opposed to servers in a data center.

[4] On the other hand presented fog computing as where processing happens on nodes physically closer to where the data is originally collected instead of sending vast amounts of IoT (Internet of Things) data to the cloud. This provides better storage, applications and data to end-users. Indicating that fog computing has good proximity to end-users and bigger geographical distribution. Fog layer is the perfect junction where there are enough computing, storage and networking resources to mimic cloud capabilities at the edge and support the local ingestion of data and quick turnaround of results, real-time analytics and improved security. To address issues related to existing models, this dissertation proposes a complete replacement of Access Points (APs) and other related infrastructure based on the conventional IEEE 802.11g/n with a Fog computing decentralization mechanism. In order to continue serving the growing number of users within the campus network domain, this work seeks to propose an upgrade to the existing hotspot infrastructure. An enhanced infrastructure will be needed to bring wireless connectivity to the campus locations, as well as to support fog layer. The proposed system will offer a cost-effective solution that will increase bandwidth to support future growth and provide wireless coverage to the majority of the campus with improved Quality of Service (QoS): latency, network utilization and capacity. Figure 1 shows the basic Fog Computing architecture.

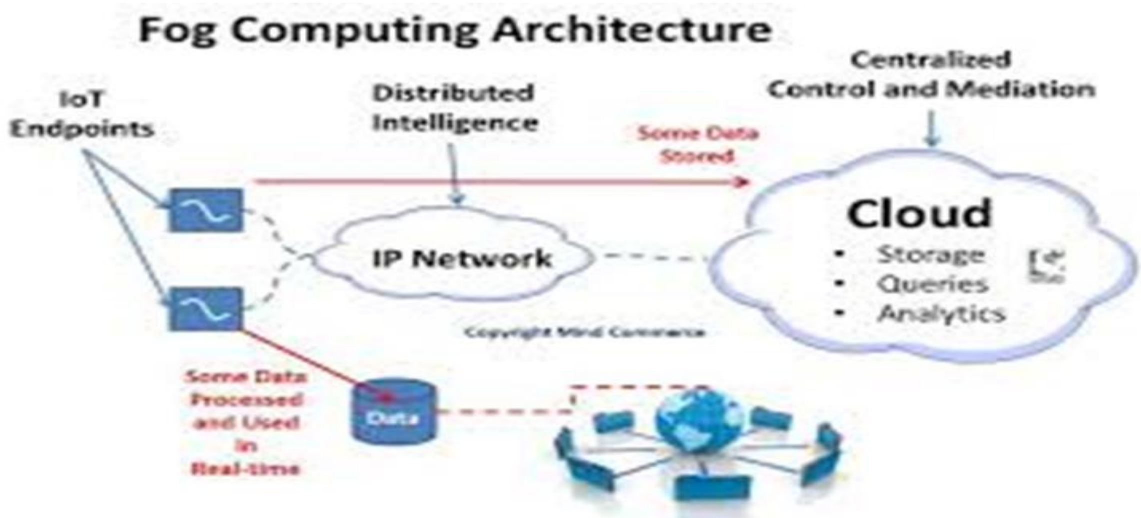


Figure 1: Typical Fog Computing Architecture (Bonomi et al, 2012)

II. LITERATURE REVIEW

Many researchers hitherto have worked on several aspects of Fog decentralization model on a Hotspot Network especially the Quality of service and network capacity. Some of such works are here reviewed. The authors in [5] explained that the rationale behind Fog decentralization model is that fog is the cloud that is closer to the ground. Hence, hotspot cloud computing carried out closer to the end users' network is thus identified as decentralized fog computing. It involves the creation of virtual platform that is located between cloud data centers hosted within the Internet and end user devices.[6] proposed that Fog computing can provide better QoS in terms of energy consumption, delay and reduced data traffic over the Internet, etc. To improve the scalability of exiting hotspot networks, edge computing and fog decentralization will be introduced to use computing resources near IoT sensors for local storage and preliminary data processing. This would decrease network congestions, as well as accelerate analysis and the resultant decision making. Ideally, edge devices in hotspot models cannot handle multiple IoT applications competing for their limited resources, which results in resource contention and increases processing latency. Hence, the Fog-Edge decentralization could seamlessly integrate edge devices and cloud resources thereby overcome these limitations. This concept basically avoids resource contention at the edge by leveraging cloud resources and coordinating the use of geographically distributed edge devices.

[7] Proposed some benefits of Fog decentralization scheme in re-engineered hotspots network to include:

i. Keeping the data close to the user: To eliminate the delays in data transfer, the fog-edge scheme allows keeping the data close to the user instead of storing them in a far datacenters.
ii. Dense geographical distribution: Fog-edge FE computing creates an edge network which sits at various points to extend the direct cloud services geographically. Isolated infrastructure helps to handle and analyze big data faster to the entire WAN because the administrators are able to support location-based mobility demands.
iii. Robustness and Scalability: FE (Fog Edge) introduces highly fault tolerant algorithms for its access points and load balancers making the network resilient.

Fog computing, however, creates a bridge-solution for the identification group and computation group: It is about forwarding the computational power to the edge of the network, where data is generated and the results are needed.

II. DESIGN METHODOLOGY

1 FEHN Network Characterization

From the equipment on ground, the network consists of 6 servers, with 528 nodes (the 6 servers represent the WLAN network of the proposed hotspot), where the hotspot is divided into 6 fog edge subnet (one for each server), each subnet has 8 gateway/access points with 16 possible Wireless Local Area Network (WLAN) clients. Here, 40% of the WLAN clients move during the entire simulation and roam among the access points of the same subnet.

Other network scenarios are:

a. On average, each station generates one packet in every 0.02 seconds
b. WLAN Beacon is set to periodic and roaming is enabled in WLAN nodes for 0.02 seconds.
c. The maximum receive life time is 0.5 seconds.

Table 3.1: FEHN Design Equipment

S/N	FEHN Design	Values
1	No of Nodes in FEHN	528
2	No of fog edge subnet	6
3	BSS Identified	1
4	AP Functionality	Enabled
5	IEEE Physical Characteristics	Extended Rate PHY (IEEE 802.11g/n)
6	Data Rate	54Mbps
7	Transmit Power (W)	0.005
8	Packet Reception Power	-95db
9	AP Beacon Intervals (Secs)	0.02
10	Maximum Receive Lifetime (Secs)	0.5
12	High Throughput Parameters	Default 802.11g/n
13	Fog Type	SRAM_ Cyclone

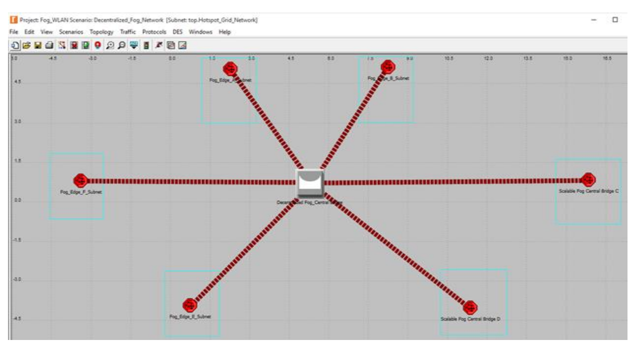


Figure 2. Fog Hotspot Decentralization Graph Model (Without Domain Clusters)

2 Mathematical Characterization of Fog decentralization

To achieve a characterization of Fog decentralization for scalability and redundant replication, a modification of the BCube leveled structure proposed by Guo et al 2009, was done using the Laguerre's function. Laguerre's function $L_n(x)$ was introduced for scalable redundancies and replication in case of disaster recovery.

$$(l+\tfrac{1}{2})^{2k} - \tfrac{1}{2} < N_s < (l+1)^{2k} - 1 + n!\sum_{K=1}^{\infty} \frac{(-n)_k}{(K!)^2} x^k$$

Where:

l = Number of links for either nodes or server clusters.

N_s =Total number of servers in a subnet cluster (FEHN$_s$).

k = Mapping Number for the node/server clusters

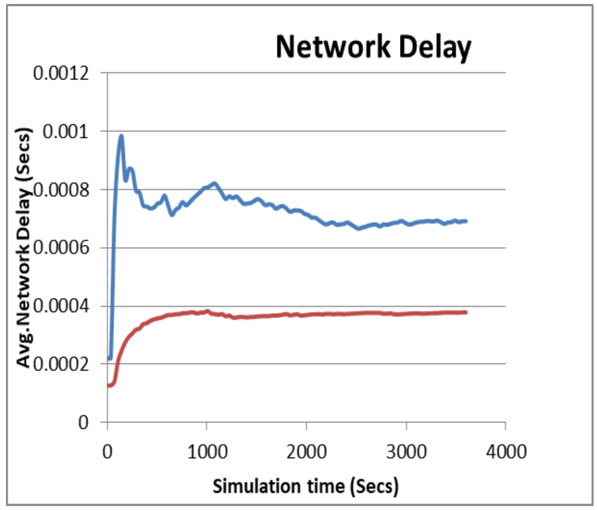
$n!\sum_{K=1}^{\infty} \frac{(-n)_k}{(K!)^2} x^k$ = Backup redundant replication with $n!$ as site coefficient,

3 RESULTS AND ANALYSIS

Simulation results analysis of FEHN for Quality of service performance in a university (NAU) hotspot network will be presented as follows;

a) FEHN Effect on Network Latency (delay)

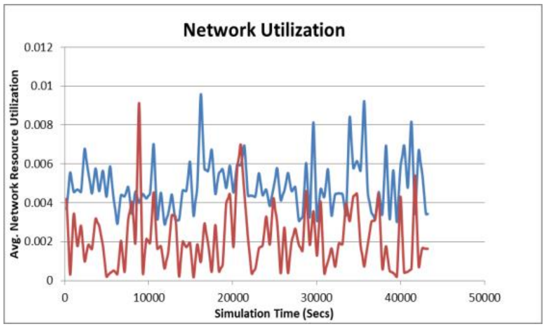
Figure 3 shows the network end-to-end delay result of the Fog FEHN two-tier topology with CLB. As depicted in the plot, the latency response shows great similarity but for the NOC, the latency response was about 0.00038secs which is much lower compared with that of the default Fog FEHN CLB scenario that has 0.0007secs. The reason for this is that in the hotspot, an incremental CLB assists in traffic optimization as well as in enhancing the overall network topology which reduces the transmission time between the access and the core layer even when the links are busy. The NOC core layer is highly redundant with little routing policy and as such can easily take packets from the access layer with very little wait states. Consequently, with the default CLB, the network delay is shown to be 63.55% while with the improved Fog FEHN CLB, the network delay is observed to be 36.45% which is smaller as well as been satisfactory for the hotspot design.



Legends: Red: FEHN Model; Blue: NAU Default.
Figure 3: Plot of Network Delay

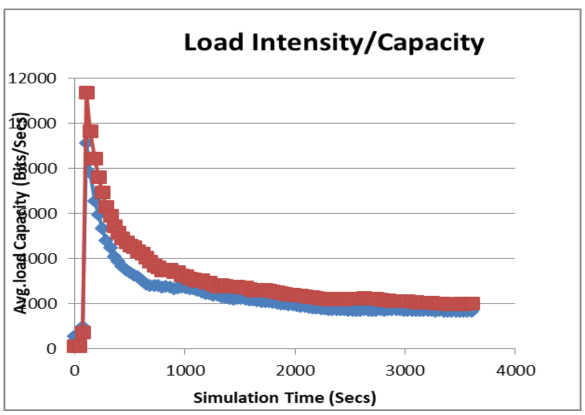
b) FEHN Effect on Resource Utilization

Service availability in the network is a function of fault-tolerance in the FEHN. In the simulation experiment, a Transmission Control Protocol (TCP) connection between servers at the core layer and the access layer was setup. Different network services including databases, E-mailing, web browsing, File Transfer Protocol (FTP), Hypertext Transfer Protocol (http) and other TCP & User Datagram Protocol (UDP) services are introduced in the two scenarios. Figure 4 shows high degree of resource utilization in the default CLB was observed 0.0057 (75%), while little utilization 0.003 (25%) is seen in the improved CLB. This scarce utilization response is ideal for high density network settings



Legends: Red: FEHN Model; Blue: NAU Default
Figure 4: Plot of Resource Utilization Effects.

It is clear that with an increase in load intensity, the more unstable the network becomes. With increase in time, the peak point is reached and then starts to drop marginally. This drops for a FEHN (improved and default) continues until at about 2000bits/sec when the network attains a stable elasticity. Similarly, stable elasticity is attained by the default at about 1900bits/sec. It is then feasible to ascertain which one has a better scalability



	Network Delay	Resource Utilization	Load intensity/capacity
NAU Model	0.0007sec (63.55%)	0.0057 (75%)	1900bits/sec
FEHN model	0.00038sec (36.45%)	0.003 (25%)	2000bits/sec
IEEE Reference Model	0.0012sec	0.007	1901bits/sec

Legends: Red: FEHN Model; Blue: NAU Default.
Figure 5: Plot of Network Load Capacity.

V. Fog Layer Hotspot Design Validations

In the validation of the IEEE 802.11 model was used as reference to show how the Scalable Model and the NAU Hotspot performed when compared. These are shown

VI. DISCUSSION

In this work, a reengineered FOG LAYER hotspot network for efficient web application integration and user experience was presented. The use of FOG LAYER devices such as servers, routers, switches in wireless data-centers running a limited number of general enterprise applications are highly effective. This is mainly because of the influence of its configurable logic blocks which can house several packets, buffer memory and bus utilization. NAU hotspots showed the limitations of the traditional hotspot network based on IEEE 802.11 with respect to latency, scalability, efficiency in web application integration, etc. A proposed fog layer hotspot was therefore designed to take care of the limitations of poor QoS provisioning and performance. Using the experimental test data gathered from NAU experimental testbed, a simulation of a compatible network is achieved and the results was analyzed. The FEHN network performed much better owing to the CLB which handle most of the limitations in IEEE 802.11 infrastructure. It was observed that FOG LAYER CLB in the entire network gave better performance in terms of throughput response, service availability, scalability, network delay, and resource utilization.

This work concludes that FOG LAYER CLB architecture is very efficient, scalable, service-oriented, and responsive to business needs, with rapid service delivery.

VII. CONCLUSION

A Comparative evaluation of QoS for the FEHN results was observed at different points. Result shows that fog layer decentralization provides scalable hotspot infrastructure with improved QoS as far as Network delay, Network load intensity and resource utilization. Overall network performance was recorded by comparing the legacy Nnamdi Azikiwe University (NAU) hotspot network to the modeled network (FEHN).

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