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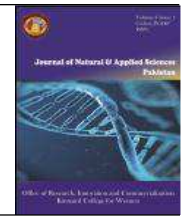

5G RADIO ACCESS NETWORKS BASED ON FOG COMPUTING: AN OVERVIEW

Tayyabah Hassan [1], Wajiha Ajmal Khan [2] , Dr. M. Rizwan [3*] , Dr. Fahad Ahmad [4,] Usman Sattar[5]
[1] Department of Computer Science, Kinnaird College for Women, Lahore, Pakistan.
[2] Department of Computer Science, Kinnaird College for Women, Lahore, Pakistan.
[3] Department of Computer Science, Kinnaird College fo Women, Lahore, Pakistan.
[4] Department of Computer Science, Kinnaird College for Women, Lahore, Pakistan.
[5] Department of Information Systems, University of Management and Technology, Lahore, Pakistan.

Article Info

*Corresponding Author
Email Id: muhammad.rizwan@kinnaird.edu.pk

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Abstract

The concept of centralization is discussed at first hand for the development of telecommunication system. Up till now, cloud computing was providing with the facilities of centralized services for computing but with the emergence of IoT, unpredictable number of devices will be producing large volumes of data for real-time applications requiring ultra-low latency which will be difficult for it to cater. So, performance degradation for cloud services will be encountered in near future. A new broadband technology, 5G networks, expected to be in operation till 2020, will be dealing with latency issues in wireless communication. 5G radio network will help power a tremendous increase in development of IoT technology. To handle real-time applications, a new paradigm has been introduced known as Fog Computing, which seems to be a solution dealing such latency issues in computing and communication. This review paper discusses the recent research that has been carried out in 5G radio access network based on fog computing: its architecture and system design.

1.INTRODUCTION

The Internet of Things (IoT) is the system of associated computing devices, mechanical and digital machines, humans and animals, or any kind of man-made or natural objects that are provided with unique identifiers, say IP addresses, through which they could transfer data to and receive from network without human-to-human or human-to-computer interaction. So it can be said that IoT is basically automating our lives [1] [2]. The term IoT has been emerged from the confluence of wireless technologies, micro-electromechanical systems, micro-services and internet. IPv6's addressing gave rise to the development of IoT. Its huge increase in address space made this possible. That means we can assign as many IP addresses to things as possible and still left with enough of them. 5th Generation wireless network system (5G) is expected to be emerged till 2020 which is the wireless broadband technology based on IEEE 802.11ac standard. Exceptional speed and coverage will be provided by 5G than the current 4G-LTE technology. Providing with up to 1 Gbps speed for tens of connections, or up to tens of Mbps speed for tens of thousands of connections, it will also cause an increase in the network expandability up to hundreds of thousands of connections [3]. IoT has taken center stage because more and more devices will be part of it in coming decades other than merely a mobile, tablet or computer. Machine to Machine communication will play a vital role in IoT in coming years so IoT-5G scenarios will contribute in sensor based IoT capabilities to robots, actuators, etc. for distributed coordination and low-latency reliable execution.

As IoT is transforming our lives, it has started generating unpredicted amount data which has become a stress for internet infrastructure along with the growing and ever changing business and industrial needs for data storage and other facilities. Cloud computing could be the solution in order to alleviate this pressure, where the cloud involves advanced virtual data centers which provide cost-effective software, information and hardware resources on pay-per-use basis [4]. It provides many benefits to the organizations with large batch-oriented tasks but certain risks are always there while relying on cloud service providers which includes security and latency issues mainly [5] [6]. So consequently, cloud computing is suitable for IT, but not for IoT.

In order to deal with latency issue, which will make this kind of infrastructure suitable for real time applications where ultra-low latency is the major concern, a new paradigm has been introduced recently that is the extended form of cloud computing, i.e. Fog Computing or Edge Computing. As more and more devices will be connected in coming years, it will become difficult even for central clouds to store such a large amount of data (say zetabytes) when information could be understood and acted upon from where it is generated‒at the edge [7] [8]. This architecture comprises of one or more end-user clients and near-user edge devices between a cloud and clients to carry out considerable amount of storage, communications and configurations, etc. Elaborating it in general, fog computing is an intermediate level computing which facilitates network services, computing and storage between clients and advanced data centers of Cloud.

In this review paper, an overview of F-RAN is given where latency issue is dealt as 5G is way more fast and reliable than 4G networks.

2.STRUCTURAL DISCUSSION AND ANALYSIS

[9] F-RAN is a new technology to resolve the issues of cloud based radio access networks. In C-RANs, the functions of computing and storage are all carried out in the centralized cloud server which needs billions of user equipment (UEs) for billions of data transmissions to the BBU pool. These centralized control functions are now brought to the fog layer comprised of High Power Nodes (HPNs), allowing UEs to access these HPNs, in order to de-escalate the workload on the cloud server. Huge transmission and delay are the two main concerns while accessing the cloud server directly, which cause burden on C-RANs. F-RANs stop stream of data transmission sent to the BBU pool by performing portion of processing in the High Power RRHs which are known as Fog access points (F-APs) or in the smart UEs. The implementation of fog computing brings about reduced complexity and latency, location awareness and better quality of service [10] [7]. Edge Caching is the prominent feature of F-RANs which makes the content at hand getting users closer to it, enhancing downloading speed ultimately, suitable for 5G networks. This caching is peer-to-peer which means

different RRHs in the cluster scale share it. This intermediate level processing can contribute to increased transmission rate if the required storage is meagre. Two different topologies can be used for fog logical layer i.e. Mesh-like and Tree-like topologies. The former may yield greater coverage of networks [9].

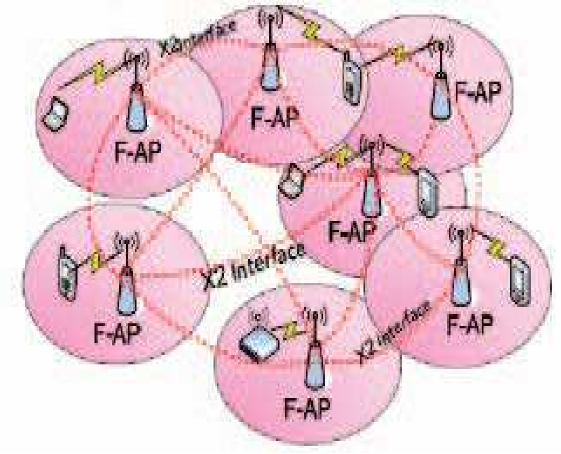

Figure 2: F-RAN with Mesh-like topology

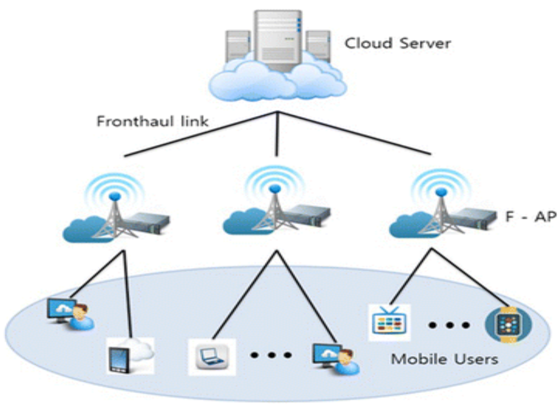

Figure 1: Basic Fog architecture

[11] Thus the integration of Fog Computing along with 5G wireless communication improves the energy efficiency and it promotes the virtualization and intelligent networking due to separation of edge and devices and to overcome the load of cloud computing, Fog computing is emerged as a vital entity for Radio network hardware in peer-to-peer wireless transmission. The impact of integration of Fog and Cloud technologies on the energy efficiency is discussed here. The coordination among devices in a Fog may lean on the Cloud. So, Cloud and Fog are inter-dependent. To analyse the performance of Fog-Cloud RAN services, energy efficiency can be calculated by:

$$EE = \frac{P}{T}\left[\frac{\text{Joule/s/cell}}{\text{bit/s/cell}}\right]$$

where T is the user throughput which could be stated as the ratio of peak data rate of RAN R and number of smart user devices N.

$$T = \frac{R}{N}\left[\frac{\text{bit}}{\text{s}}\right]$$

and P is the user power consumption given by:

$$P = \alpha T + \beta \left[\frac{\text{Joule}}{\text{s}}\right]$$

or

$$P = \alpha T + \beta \;[\text{W}]$$

Here, α and β are the data transfer power coefficients for each type of RAN, the values of which are given in table below [12]:

Table 1: power coefficients for specific RAN

RAN	α [mW/Mbps]	β [mW]
3G	122.12	817.88
4G	51.97	1288.04
5G	6.5	11475.97

[13] The computing time and communication time (also known as hop count) in F-RANs change according to the mobile users demand and also the supply of fog servers in network system. Longer processing or computing time will be taken by a fog node with greater workload. In other case, even if the resources are available in neighboring fog nodes, still it will lead to a much longer transmission delay despite the fact that lesser computation time is taken [14] [15]. So the fog nodes can be preordained to deliver better quality of service by setting an optimal target for the consummation of workloads. By knowing these factors, the efficiency of the whole system can be increased. Evaluating it in mathematical form:

$$\min_{w} \quad \frac{\sum_{r=1}^{R} w_r}{\sum_{k=1}^{K} w_k}$$

The ratio between the sum of number of rejected workloads w_r and the sum of total number of workloads in the system w_k gives the blocking probability [13]. Before finding minimum blocking probability, following constraint must be satisfied by the system: the total latency of an accepted workload wa, composed of the computing delay and the communication delay, must not go beyond the accepted threshold which is the maximum tolerant latency of a service. All fog nodes which satisfy this constraint are considered in the list of candidate nodes for providing better quality of service.

[16] Some recent advancement in the F-RAN architecture includes the hybrid fog-cloud architecture to leverage the best features of both Fog and Cloud computing. This convergence of Cloud and Fog architectures in 5G RANs will be supporting various applications of different kinds in a better way. This hybrid approach comprises of four types of clouds: global centralized communication and storage cloud, centralized control cloud, distributed logical communication cloud, distributed logical storage cloud.

[17]. Responsive management of resources and radio signal processing carried out in subordinate F-APs, is done by the global centralized communication and storage cloud in BBU pool. The logical fog layer, responsible for coordinated communication and storage, containing edge devices like RRHs, F-APs and user equipment (UEs), serve its purpose in F-RANs supporting device-to-device (D2D) communication with other UEs. These edge devices perform application processing tasks to reduce latency and traffic congestion in the BBU pool. Moreover, coordinated and cooperative functionalities among all the devices can be provided by the adjacent edge devices by linking them with each other.

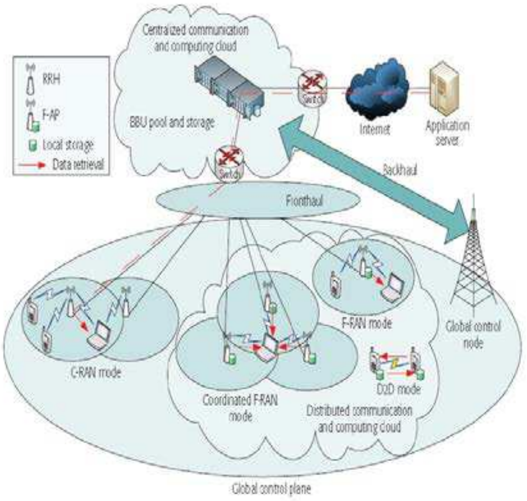

Figure 3: Fog-Cloud RAN hybrid architecture

Two approaches are used to combine the computing functionality with 5G communication networks: loosely coupled and tightly coupled approaches. *Mobile Edge Computing platform (MEC)* is the loosely coupled approach for mobile edge applications, in which a new computing resource is used as an infrastructure [18]. This computing resource is managed by mobile edge host which deals with the status of the mobile edge applications. Another one is the *General Purpose Processor platform (GPP)* which is considered as the tightly coupled approach [19]. This approach in wireless networks will lead to another paradigm switch in coming future. In GPP platform based F-RANs, specific or dedicated processing resources responsible for applications and communication processing will be replaced by general-purpose computing unit running all the processes. It will help manage computing resources in efficient manner in a way that shared resources could be used for computing and communication.

With the emerging IoT technology, everything in life is going to be automated which will definitely be generating unpredictable volume and variety of data. With the generation of such large volume of data, even the highly optimized virtual data centers of Cloud will be insufficient in providing storage services. Moreover, IoT demands requests to be dealt in real time. Any delay will not be tolerated for these kind of applications and few requests might not need storage services rather, need to be processed rapidly. In short, present Cloud models are not designed for the data IoT will generate. In this review paper, an overview on 5G radio access networks based on Fog computing is presented. Fog computing based RANs have been justified to better support real-time applications requiring ultra-low latency which is the main target of upcoming 5G networks [20]. This new paradigm is the extension of Cloud computing as Fog brings Cloud services near to the devices producing time-sensitive data. A comparison of QoS parameters for Cloud and Fog computing is presented below which can clearly determine the utility and effectiveness of Fog computing over Cloud [14].

Table 2: QoS parameters for cloud and fog computing

Type	Processing Layer	Avg. Tuple Delay (sec)	Avg. Network Usage Time	Avg. Network Length(Bytes)	Avg. Energy Consumption
Cloud Computing	IoT to Cloud	181.17	83.16	65.71	100.29
Fog Computing	IoT to Fog	61.70	12.15	8.69	35.78
	Fog to Cloud	24.02	13.81	15.59	17.21
	Total	95.72	25.96	24.28	52.99

3.CONCLUSION

The process to calculate energy efficiency of the integration of Fog Computing and Cloud Computing technologies have been discussed briefly along with the two approaches to integrate computing with communication, as the main focus of this paper was to analyze 5G radio access networks having Fog Computing technology. The analysis of F-RANs to provide better quality of service by reckoning minimum blocking probability is also discussed in this review paper. Fog computing can be the more suitable solution to all the incompetencies of Cloud computing in a way that the requests will be analyzed, processed or configured at the edge by the near-user edge devices also called Fog nodes. Fog Computing outperforms in terms of Average Tuple Delay, Average Energy Consumption and Average Network Usage Time as compared to Cloud Computing.

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