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Performance Evaluation of IPTV Zapping Time Reduction Using Edge Processing of Fog RAN

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ABSTRACT

Internet Protocol Television (IPTV) is a promising technology that can provide TV broadcast services everywhere and anytime in next-generation wireless networks. However, channel zapping delay time between two successive channel switches is one of the key metrics that may hinder viewers' satisfaction with the IPTV system. Several factors are contributed to prolonging the switching delay such as the delay of the access link that could be generated by the underlying network. In this paper, the minimization of the zapping delay is investigated using the concept of Fog Radio Access Networks (F-RAN) architecture. F-RAN will bring the access points closer to end users (cloud edge). This merit can be utilized an advantageous aspect for minimizing the zapping time of IPTV system due to the low latency communication over F-RAN architecture. To testify the improvement in the IPTV system, an experimental investigation method is applied based on various simulation scenarios. This would be achieved via identifying the problem of the zapping time from the correlated literature, followed by examining the associated causes for this delay. Furthermore, the F-RAN architecture has been proposed as a solution to the part of Zapping Time (ZT) latency that originates from the communication architecture. Additionally, the simulation design is developed based on assessment of two types of cellular architectures, which are the full centralized processing C-RAN and the distributed edge processing F-RAN architecture. The performance evaluation is measured based on the comparison of zapping delay time in both of the F-RAN architecture with the corresponding full centralized C-RAN architecture. Simulation results demonstrate a noticeable reduction in the zapping time with the F-RAN compared to the virtualized C-RAN architecture. Hence, the zapping delay time can be optimized with the application of F-RAN architecture.

1. INTRODUCTION

The shifting towards Internet-based services is one of the key trends in the present and future technologies [1]. This is coming side by side with the noticeable convergence between IP communication and broadcasting. Internet Protocol Television (IPTV) system has gained a particular interest recently to provide ubiquitous TV service delivery, via the Internet as a transmission medium. This means that a full package of services can be provided by the Internet including surfing the web, free internet-based mobile phone calls, and the provision of TV channels are also included altogether to the end-users [2]. One of the open research problems in the IPTV system is the challenge of zapping time when the user tries to switch from one channel to another. In IPTV system, the delay may extend to several seconds, which requires lots of effort from the service providers to meet the user's satisfaction with the provided service [3], and this is commonly known as the Quality of Experience (QoE). Hence, QoE is a key metric that measures the success of the IPTV system [4]. Unlike the Quality of Service (QoS), which is exclusively related to measurements of networking parameters (e.g., packet loss, jitter, and delays), the QoE is a measure of the level of customer satisfaction with the service offered by vendors. Hence, there is a positive impact when customer's experience with high quality TV channels that display “immediately” on screen using the IPTV service. Prompt response in IPTV system can be considered as a competitive factor between operators. However, the zapping delay between two successive channels may lead to inconvenience by the end users.

Zapping time may be an obstacle to the expansion of IPTV system service. Unlike the traditional broadcasting TV system which can display the channel content in a small time, the receiver device of the IPTV technology, cannot receive all channels simultaneously over the IP-based network due to bandwidth limitation [5, 6]. On the other hand, the IPTV system presents a promising technology to provide smart services such as detecting the essential channels based on the preference and the behavior of the users [7].

Fog Radio Access Networks (F-RAN) has been developed as a promising cellular architecture that can meet the requirement of future low communication latency applications [8]. Hence, F-RAN architecture is proposed in this work to examine the possibility of reducing the Zapping Time (ZT) via utilizing the property of edge computing in F-RAN architecture. The remainder of the paper is organized as follows: in section 2, a concise review of the prior work is demonstrated. In Section 3 a theoretical explanation for the IPTV system, zapping time, along the F-RAN architecture are presented. In Section 4, the proposed structure of the IPTV/F-RAN is demonstrated. Section 5 illustrates the evaluation and the discussion. Finally, Section 7 contains the conclusion of the paper.

2. RELATED WORKS

The Reducing zapping time is an attractive research topic for academia and the industry. As mentioned earlier, since the channel change time is a central prerequisite for the user's QoE, Basicevic et al. [3] mentioned that the operators have to tackle this problem seriously. In fact, in the IPTV system, the delay can be generated from several sources as shown later in next sections. Hence, various research studies have been conducted to tackle and minimize the sources of this delay that leads to speed up channel changing time in the IPTV systems.

Joo et al. [5] focused on the channel prefetching techniques to minimize the zapping time. The prefetching is deployed based on the concept of channel reordering. Lee et al. [9] introduced the principles of channel identification in the IPTV system which surpasses the prefetching methods by identifying near future channels of the viewer. Li et al. [10] studied the viewing behavior of the user to measure the potential factors that can affect channel changes. Likewise, Hussain et al. [11] proposed pre-join methods to decrease the time of multicast operation of channel zapping via selecting the next most likely channel of the user. Sarni et al. [12] suggested a low-quality stream to gain faster random-access point detection in groups of pictures. Basicevic et al. [13] applied a pre-tuning technique to find the target of subsequent zap of the adjacent channels. In a similar context, Cha et al. [14] proved that 62% of changes in the channel are completed by either zapping to next or to the previous service.

Adeliyi et al. [15] proposed a unicast IPTV-based service instead of a multicast service, although this solution has been proved not viable later due to the expansion in the number of subscribers. Furthermore, Nikoukar et al. [16] designed an approach to deliver the adjacent channel together with the requested channel. However, the subscribers are not switching to the adjacent channel all the time. Two research studies conducted by Khosroshahi et al. and Adeliyi et al. [7, 17] to propose a technique for predicting the subscriber's desired channel to prepare the next channel in advance and then minimize the zapping delay. Another field of research has been focused on improving the video encoding techniques to minimize the zapping time as demonstrated by Joo et al. [18]. However, still, there is an unsatisfactory approach due to the obligatory decoding delay that is restricted by the video buffering delay and the coding standard. Abdollahpouri and Wolfinger [19] tried to minimize ZT by using the pre-joining tuning technique thru pre-buffering and pre-joining the probable channel that may be selected subsequently along with the current watched channel. It is important to note that with all of the undertaken studies, still further research is required to investigate the possibility of optimizing the zapping delay in the IPTV system service. This is particularly with the evolution of High-Definition Television (HDTV) and Ultra-HDTV which have high bandwidth demand.

In this paper, the focus is on the possibility of minimizing the amount of ZT using the concept of Fog Radio Access Networks (F-RAN) architecture of cellular networks. F-RAN can be utilized to minimize the amount of the ZT of IPTV system, where to the best of the authors' knowledge, no prior work investigates the correlation between the amount of ZT and the corresponding type of cellular network architecture. F-RAN architecture is nominated due to its superior features that can be employed to reduce the ZT compared to the Cloud-RAN (C-RAN). This is because latency minimization is one of the key characteristics of F-RAN architecture, which maintains by employing processing elements closer to end users at the edge of the network.

3. RESEARCH COMPONENTS

Throughout this section, the main components of this research are explained and clarified including the IPTV system, zapping time problem, and the evaluation of RAN in cellular networks.

3.1 Mobile internet protocol television wireless networks

In the earlier time of the IPTV system, the service has been provided without mobility using a wired access network with a special device known as Set-Top Box (STB) which is co-located with TV sets. Later, the continued development in wireless technology has paved the way to access the Internet from anywhere at any time.

Table 1. A comparison between the legacy wired-based and the wireless access network of IPTV system [20]

IPTV System (Features)	Wired Access Network	Wireless Access Network
Mobility	Mobility is not a consideration (fixed)	Mobility support
Cost	High deployment expense	Cost-effective with less infrastructure requirement
Upgrade	Difficult for upgrading	Easy upgrading
Bandwidth sharing	Dedicated TV channels bandwidth (no contention)	Shared the overall bandwidth
Channel zapping time	In a cable-based TV system, channel changing time is very fast (no tangible delay around two seconds)	Higher channel switching delay due to many aspects of wireless architecture
Duplexing technique	Frequency	Time and frequency

Table 1 presents a brief comparison between the traditional and wireless access IPTV system. IPTV represents an integration of television services to high-speed networks. This enables IPTV to support a seamless wireless communication environment to provide TV channels in real-time over IP networks. Wi-Fi is the most common technology that has been used with IPTV systems over home networks. However, employing Wi-Fi as a shared wireless home network can form a bottleneck point particularly with the multimedia applications that require high bandwidth demands. Hence, the cellular network is a promising technology that can be utilized to provide ubiquitous live broadcast services (TV channels) at the high Quality of Service (QoS), quality of experience, security, and reliability [21]. The main challenges of the IPTV system are the rate of packet loss; packet jitter; the end-to-end delay and the channel zapping time [22].

3.2 Zapping delay time problem

Channel zapping time occurs when the user switches from one TV channel to another as shown in Figure 1. It is worth stating that in the traditional cable-based TV, channels are received simultaneously with a very short zapping time without a noticeable delay. However, in the Internet-based platform, several factors or limitations may lead to generating zapping time around (0.9-70) seconds throughout switching of channels [23]. Consequently, high delays lead to users unsatisfactory with the IPTV system. Hence, zapping time is one of the key factors that affect QoE regarding the service of the IPTV system perceived by subscribers.

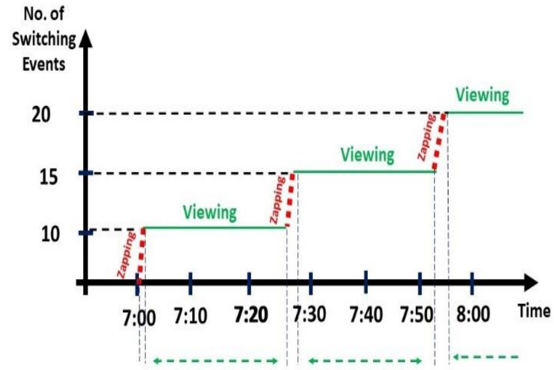

Figure 1. Illustration of channel zapping time and viewing time

There are several sources of zapping time delay. The key components of this delay as illustrated in [14, 24-26] including 1) the Internet Group Management Protocol (IGMP) that is responsible for sending messages through the network to join the new channel and leave the previous one; 2) the synchronization delay which is described as the time between the reception of reference I-frame at the STB and the beginning of the decoding process; 3) buffering delay, which is the time of buffering video frames. It is worth stating that the operation of IGMP communication protocol is presented by establishing a multicast group membership for IP based networks of online streaming videos. In other words, IGMP is used to direct the multicast transmission to the hosts based on their requests. Hence, the delay that is induced in the network during the IGMP transmissions can be referred theoretically as a network delay. Regarding the theoretical discerption of zapping delay time in the IPTV system, the authors in [27] have describing mathematically the zapping time via dividing the delay into three main parts as shown in Eq. (1) as follows:

$$Z_T = DT_s + DT_b + DT_N \tag{1}$$

where, Z_T is channel zapping delay time, DT_s is the average synchronization delay, DT_b is the buffering delay, DT_N is the network delay, which includes IGMP delay.

$$DT_s = \frac{\delta}{2\theta} \tag{2}$$

where, θ is no. of frames per second for the broadcasted videos, δ is the no. of frames within the group of pictures.

$$DT_b = \frac{\mu\delta}{\theta} \tag{3}$$

where, μ is the essential group number of pictures in the receiver to begin playing.

$$DT_N = \sum_{k=1}^{m} p_i \, \tau_i \tag{4}$$

where, p_i is the probability to join the group of multicasts at node k, τ_i is the time duration from the transmission of the request of video chunks until receiving the video chunk, m is an index for the sender.

3.3 Evolution of radio access network from dedicated hardware to cloud and fog cloud

In a mobile network, the Radio Access Network (RAN) has been evolved chronologically definitely to meet the new demands of cellular networks such as the massive number of subscribers, the QoS provision and at the same time to increase the revenue of mobile network operators. Starting from the 4G LTE Distributed RAN (D-RAN) network architecture which represents the point of change towards the virtualization. In LTE/LTE-A, the RAN includes a physical base station (eNodeB) connected via the fronthaul communication link to the access points or the Remote Radio Heads (RRHs). However, this paradigm has several challenges such as high deployment costs, cell interference management, high energy consumption, and traffic load management, for more details, the interested reader may refer to [28, 29].

In the C-RAN architecture [30], a new concept has been introduced to cellular networks, which is the virtualized RAN that is moved into cloud computing to utilize the features of the cloud such as processing and storage capabilities. Interestingly, C-RAN can solve most of the challenges of the traditional hardware-based or known as distributed RAN network. C-RAN, however, also has some challenges in the deployment including the high burden on the fronthaul communication link in terms of capacity and latency constraints which leads finally to decrease the spectral efficiency. Hence, to overcome of the challenges of C-RAN, the Heterogeneous C-RAN (H-CRAN) architecture has been developed [31] to decouple the control and user planes.

H-CRAN unfortunately still has disadvantages [7] represented by first the operators have to use a high number of RRHs to meet high-capacity requirements. In addition to a low gain is achieved from the storage and processing of the edge devices RRHs and smart User Equipments (UEs) to lighten the load between the fronthaul and the virtual BBU. Besides, the traffic data between RRHs the pool of BBUs can include redundant information that affects the constraints of the fronthaul. To solve the aforementioned challenges, the concepts of Fog-RAN have been proposed as revolutionary architecture [7, 32]. F-RAN is an architecture that brings some of cloud computing capabilities from the center to the edge of the network including communication, storage, control configuration, and management. This evaluation brings several new features and services, such as support of low latency applications, mobility, and a huge figure of nodes with position awareness. F-RAN is alternative solution for signal processing when the cloud providers have no data center at certain locations [33]. F-RAN supports wireless services and it can integrate with the present and future cellular network. Figure 2 illustrates the three key architectures with the manner of signal processing.

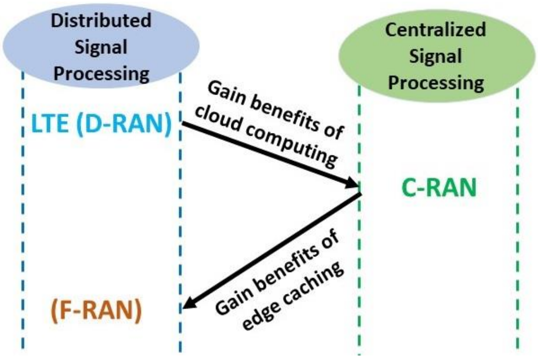

Figure 2. Distributed versus centralized signal processing of common cellular architectures

4. ZAPPING TIME MINIMIZATION USING F-RAN

Fog computing has been designed as a solution for latency-sensitive applications [34]. Hence, unlike the traditional centralized C-RAN, the F-RAN represents an extension to cloud computing that can maintain low latency requirements via applying the data processing locally closer to the end-users at the edge of the cloud. In other words, the distance between end-user and server will be one hop instead of multiple hops of the legacy cloud computing structure [35]. Hence, the zapping time delay will be minimized with the application of the F-RAN network. The access points are equipped with local caches and processing units that enable quick access and retrieval for the content. Figure 3 represents the C-RAN architecture that has centralized storage, processing, and caching capabilities in cloud computing, which results in a high burden on the fronthaul transmission medium. On the other hand, Figure 4 demonstrates the propose IPTV based F-RAN architecture which is originally proposed to overcome the challenges of C-RAN by bringing an extension of the cloud computing to the edge of the network. Hence, the requests of UEs will be delivered at lower latency requirements.

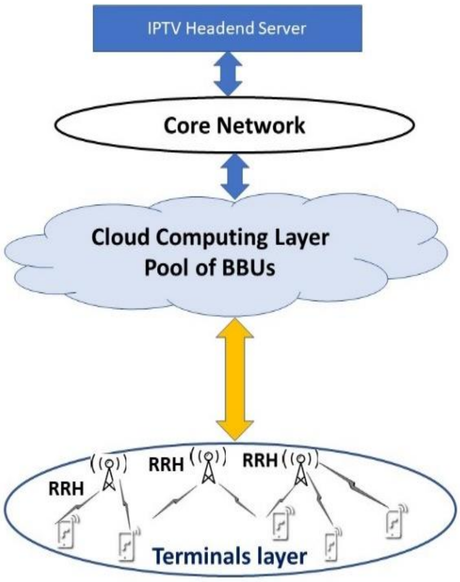

Figure 3. Full centralized C-RAN - IPTV architecture

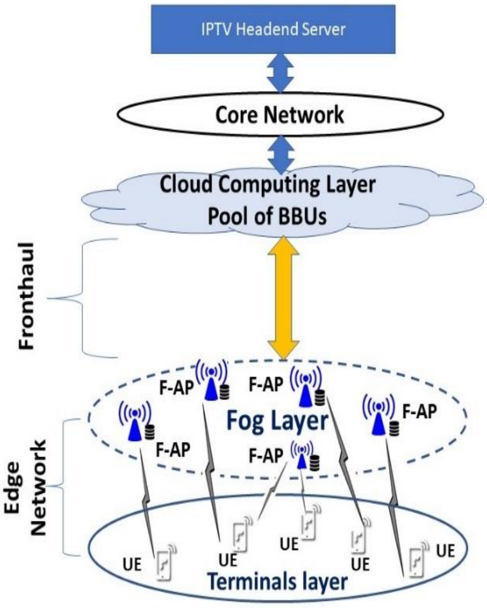

Figure 4. F-RAN-IPTV architecture

The data flow in Figure 5 and Figure 6 illustrates how the mechanism of IPTV signaling engages cloud computing in both the join phase and the replied phase, which represented by the stream of TV channels that has been already requested by the UE. On the other hand, in the F-RAN the processing and caching will be within the edge nodes mini-cloud units (F-APs), which results in minimizing the channel zapping delay time that is resulted from the reduction in network delay since the processing is moved from the central cloud to be closer to UEs at the edge nodes.

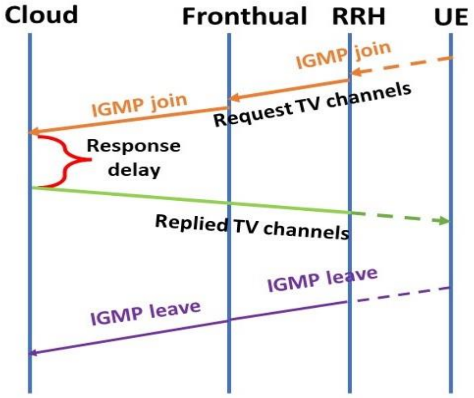

Figure 5. IPTV dataflow in C-RAN architecture

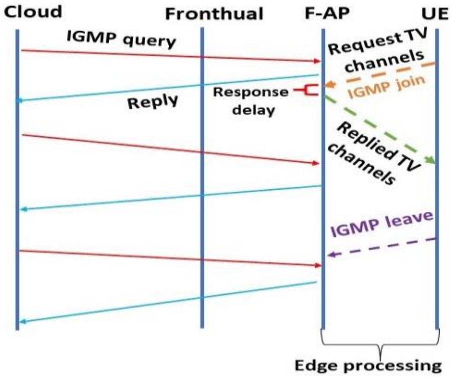

Figure 6. IPTV dataflow in F-RAN architecture

Hence, as demonstrated in Figures 4 and 6, the advantageous aspects of F-RAN can be utilized now in provisioning the IPTV service. Unlike the full centralized C-RAN, moving processing to the edge of the network closer to the end user as in F-RAN can reduce both the communication and processing burden. In other words, there is a trade-off between the centralized processing paradigm, which requires to response for the entire number of requests as in C-RAN at higher response time. Instead, the distributed processing at the edge of the network as in F-RAN architecture, it will definitely minimize the response time to the associated users. Hence, the channel changing latency is lower in F-RAN compared to C-RAN architecture.

5. THEORETICAL ANALYSIS OF ZAPPING TIME REDUCTION IN F-RAN NETWORKS

This section presents a concise analysis of the key aspects that can improve the network performance under the deployment of F-RAN, which can lead to minimizing the ZT of the IPTV system. For the network model, it is assumed that the F-RAN network is deployed with, N_i number of UEs (i=1, 2, …, N_i), which are served by M_j number of F-APs (j=1, 2, …, M_j) all have similar storage capacity in terms of local caches. The evaluation scenario is conducted between the C-RAN architecture with the F-RAN as illustrated in Figure 7.

The enhancement in the deployment of F-RAN is analyzed based on two points of views, including the communication concept along with the processing capabilities.

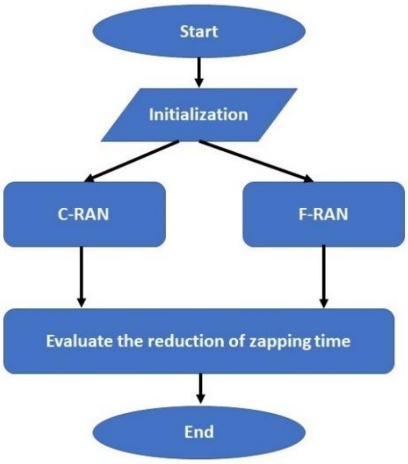

Figure 7. Flowchart of the proposed evaluation procedure

In the part of communication analysis, the Signal to Noise Ratio (SNR), the path loss, the received power, and the average link throughput are investigated.

For a single-hop wireless transmission between the UE and the F-AP (which represents an access point with light storage and processing capabilities), the SNR formula can be calculated as follows [36]:

$$SNR_i = \frac{P_s K \, 10^{\frac{\delta_s}{10}\varphi}}{d^{\propto}\left(\sum_1^J P_j + Th_{UE}\right)} \tag{5}$$

where, P_s is the transmission power, P_j is the interference power, d represents the distance between the UE and the F-AP, K and α are constant parameters inferred from propagation loss, K is Boltzman constant, L_{tr} is the penetration loss, $\propto$ equals 3.5, Th_{UE} is the thermal noise of the UE, φ is a standard random variable for modeling the fading, δ_s is the standard deviation of the shadow fading.

According to Eq. (5), the SNR is inversely proportional to the value of the distance d. Hence, theoretically with the deployment of F-RAN, the SNR will be improved and this leads to improvement in the channel capacity as shown in the following expression [37].

$$C = \sum_{HN}\sum_{CH} BW_i \; log_2(1 + SNR_i) \tag{6}$$

where, BW_i is the bandwidth assigned to channel (i). Equation (6) shows that the overall capacity C corresponds to the summation of all Heterogeneous Networks (HN) cells and all their corresponding Channels (CH). It is worth stating that the most common routes that can be followed to increase the network capacity are (i) enlarging the number of access points of different types (heterogeneous), which is the core idea of using Fog-RAN with the dense deployment of Fog nodes; (ii) increasing the total number of channels; (iii) increasing the system bandwidth such as using higher frequency band in centimeter and millimeter waves [38], and finally (iv) increasing the SNR such as bringing the F-AP closer to the users. The next term considered is the wireless channel path loss. From a theoretical point of view, shorter distance means lower path loss and vice versa as illustrated in Eq. (7) [39]. Figure 8 describes the correlation between the path loss and the corresponding distance. It can be noticed that as the distance increases in the communication link, the attenuation in the radio frequency wave is increased as well. Likewise, the received power based on the Friis formula in Eq. (8) will be higher as the distance decreases (Inverse relationship) as shown in Figure 9.

$$PL = 92.4 + 20log10(d) + 20log10(f) + \propto(d) + \rho(d) + \epsilon + \delta_s \tag{7}$$

where, PL is the path loss, d distance between the user and the F-AP, f is the frequency, ρ is the rain attenuation, ϵ is the Foliage losses, and δ_s is the standard deviation of the shadow fading.

The received power can be expressed as follows.

$$P_r = P_t G_t G_r \left(\frac{c}{4\pi d f}\right)^2 \tag{8}$$

where, P_r is the received power, P_t is the transmit power, G_t & G_r represent the transmitter and the receiver gains respectively, and $\boldsymbol{c}$ is the speed of light.

In fact, using the F-RAN can significantly improve the network performance via utilizing the merits of this architecture. These merits are thoroughly explained in [30]. The latency minimization is at the forefront of the advantages of the F-RAN architecture. The applications of fog end nodes not only reduce the communication latency but also minimize the fronthaul load traffic effectively since there is no need to pass through a long transmission network to the remote core network for processing. According to [40-42], in F-RAN, with the dense deployment of edge fog nodes, the user can access the F-AP's which are nearby. Unlike the C-RAN, in F-RAN, the latency that may generate from the propagation delay as well as from the centralized computational overhead will be significantly reduced due to the decentralized management [43]. Improving SNR in F-RAN architecture increases channel capacity as shown in Eq. (6) which consequently leads indirectly to minimizing the zapping delay. In fact, the low network capacity means that the incoming data may reach the network capacity and this increases the delay sharply by adding waiting time for the queues of all nodes in the path, which is known as network congestion. Hence, in the F-RAN scenario the overall network delay τ_i shown in Eq. (2) will be decreased significantly. The second part of analysis of ZT with F-RAN architecture is represented by the distributed signal processing over the edge nodes instead of full centralized processing as in C-RAN. The advantageous aspect of employing the F-RAN architecture in the IPTV system can be analyzed using the concept of divide and conquer algorithm as demonstrated in Algorithm 1. This is due to fact that the operation nature of the F-RAN architecture is relied on the concept of dividing the processing of large tasks that had been resulted previously from huge number of UEs as in the centralized processing paradigm of C-RAN to be in form of distributed chunks via allocating a specific number of UEs to each server (edge node). Hence, the edge node can deal with the its edge UEs only.

Algorithm 1: Divide-and-Conquer (general concept)

```
Input: Problem to be solved, Minimum_ Size_Threshould.
Output: Solution at low time complexity.
If the problem size <= Minimum_ Size_Threshould
then
Solve the problem directly
Return (solution)
End if
Else
Subdivide the problem into (n^th) subproblems
Then
Solve the subproblems in parallel manner
Combine the solutions of subproblems
Return (solution)
End for
End function
```

Regarding the time complexity of a divide-and-conquer algorithm can be expressed as follows:

$$T(n) = \begin{cases} T\left(\frac{n}{k}\right) + f(n) + c\ , & n > Min\_Size\_Threshould \\ 1 & , \ n \leq Min\_Size\_Threshould \end{cases} \qquad (9)$$

where, n: size of input, c: is a real constant. $\left(\frac{n}{k}\right)$: size of each subproblem. All subproblems are assumed to have the same size each requires $T\left(\frac{n}{k}\right)$ time. $f(n)$: cost of the work done outside the recursive call, which includes the cost of dividing the problem and cost of merging the solutions.

For parallel Divide-and-Conquer Algorithms, the function of complexity of the divide-and-conquer algorithm can be determined in O(log$n$) parallel time. The operation of F-RAN architecture is compatible with the concept of Divide-and-Conquer Algorithms since it enables the network to divide the signal processing tasks into several servers (fog nodes). This can be achieved via moving the computation from the cloud into the fog nodes to manage the processing of a delay sensitive applications. This can be expressed mathematically using M/M/C queueing system as the $\rho = \frac{\lambda}{N\mu}$ instead of $\rho = \frac{\lambda}{\mu}$, where, ρ is traffic intensity (utilization factor), λ is the arrival rate, μ is the service rate and N is number of parallel servers.

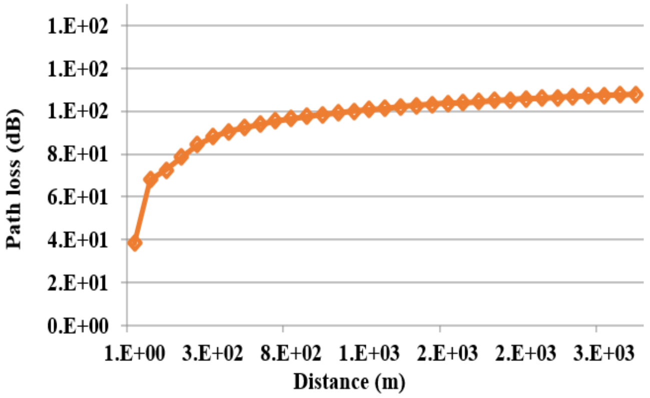

Figure 8. Path loss versus distance

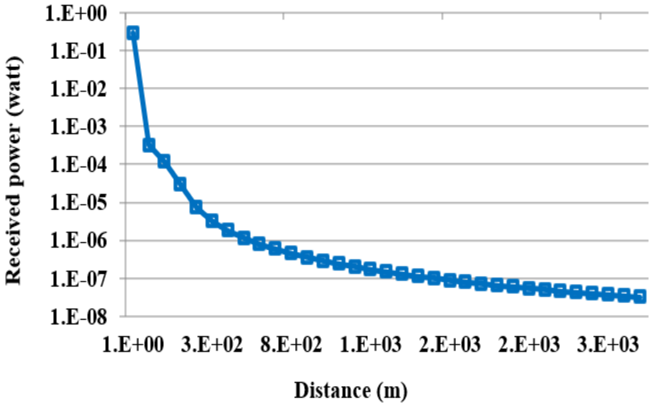

Figure 9. The trade-off between distance and power

6. PERFORMANCE EVALUATION AND DISCUSSION

In this section, a simulation for streams of real video is conducted. The performance is measured based on the main metrics of the IPTV system including zapping delay time, channel capacity, and Peak Signal to Noise Ratio (PSNR), performance. A comparison of the obtained results is done between the IPTV-C-RAN architecture and IPTV-F-RAN architecture. Table 2 illustrates the settings of simulation parameters. For the sake of simplicity, the buffering delay and the decoding delay are considered as constant delay.

The result depicted in Figure 10 demonstrates the impact of ZT reduction with increasing the link data throughput in the IPTV system. In general, the results show that when the throughput of the link increases, the zapping time decreases proportionally. For the F-RAN architecture, there is a noticeable reduction in the zapping time due to the superior performance of the F-RAN over the C-RAN architecture. Furthermore, in Figure 11, the PSNR is improved compared to the C-RAN architecture. This is due to fact that the PSNR is inversely proportional to the distance between the UE and the F-AP. This improvement is due to the closer caching and processing capabilities at the edge of the network (low distance transmission link). Consequently, the data rate based is improved which is compatible with the principle of channel capacity formula in Eq. (6). In addition, Figure 12 depicts how the zapping time is increased in both the C-RAN and F-RAN architectures with the growing up the number of concurrent IPTV channels in the network. It can be noticed that although the ZT starts to increase in both architectures, However, the F-RAN outperforms noticeably the C-RAN in the amount of the produced ZT delay. This is due to that the processing is managed in edge caching units closer to the user in a distributed manner. Additionally, the increase in ZT with C-RAN starts to grow up exponentially due to the overhead of signaling of fronthaul and backhaul. While the growth in ZT is slight in comparison, as the signaling is shared among all distributed F-AP in F-RAN architecture. Table 3 demonstrates that the deployment of F-RAN with the IPTV system can improve the performance significantly by minimizing the ZT compared to related literature. It is worth stating that the ZT delay is originated from different sources. Hence, the other contributions shown Table 3 can be integrated with the proposed work in minimizing ZT, where each of them can support ZT minimization when functioning concurrently.

Table 2. Main simulation parameters [26]

Parameters	Value
No. of F-AP	5
No. of UEs	20 per F-AP
No. of channels	100
Routing strategy	Shortest Path
Caches capacity	5120 chunks
Simulation time	1 hour

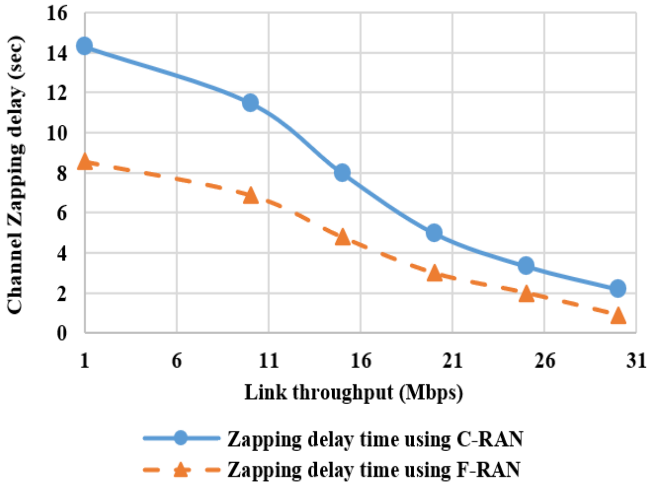

Figure 10. Zapping delay time minimization with increasing link rate in F-RAN and C-RAN architectures

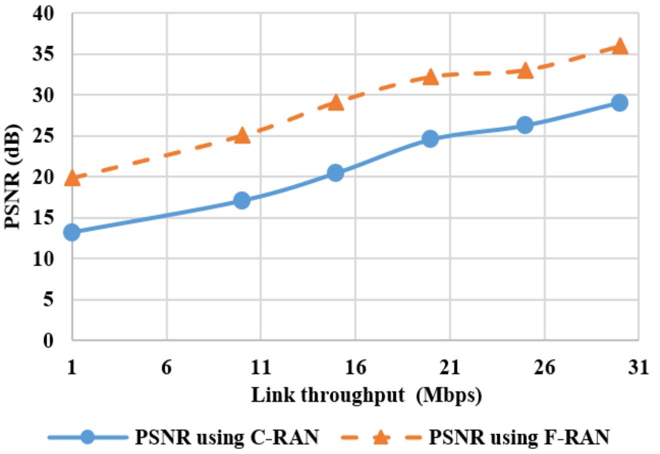

Figure 11. The PSNR level vs. data rate of links

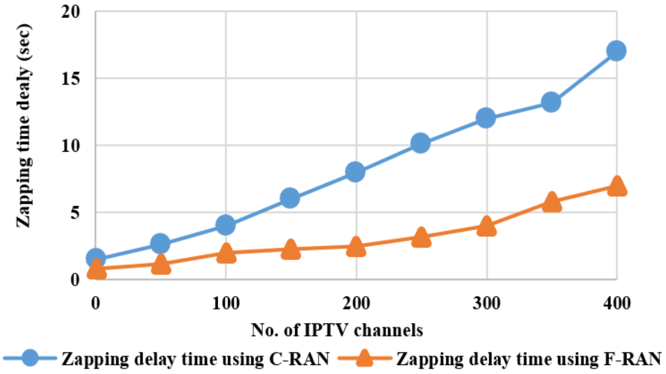

Figure 12. Zapping delay time vs. number IPTV channels

Table 3. Performance comparison of literature related to ZT minimization

Work	Approach	Results (average percentage of ZT minimization)
[5]	Channel prefetching	23%
[6]	Subscriber's desired channel	34%
[8]	Channel identification	37%
[11]	Additional multicast stream	21%
[18]	Channel distribution and video encoding	26%
[19]	Prediction-based prejoin mechanism	30%
Proposed work	Edge processing of F-RAN	59%

7. CONCLUSIONS

IPTV will be the theme of TV service worldwide and will be provided through the advanced wireless network such as 5G network and beyond. However, IPTV is a delay-sensitive system. The channel zapping time is one of the main challenges in the IPTV system which needs to be optimized to provide better QoE for all users. The delay in changing channels can negatively affect the QoE of IPTV users. F-RAN architecture can minimize the ZT delay via the edge light storage and computation capability known as fog-nodes (e.g F-AP).

The proposed architecture has addressed the zapping time with two folds. Firstly, reducing the compunction delay using shorter paths between the F-AP and users. Secondly, minimizing the computational complexity by using distributed processing, where each region is served by its own F-AP.

The performance has been evaluated in terms of PSNR, link throughput, and number of active users. The results reveal that bringing the processing and caching at the edge of the network in the F-RAN architecture can significantly minimize the zapping delay. This is due fact that the processing can take place near the end users in the physical proximity from F-AP.

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