Analysis of Quality of Experience (QoE) in Video Streaming and its Improvement in 5G

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Abstract—*Today, the fast proliferation of mobile phones, tablets, and PCs connected under the network and the need for multimedia streaming and live streaming, and other requirements has led to the development of 5G from 4G networks. The 5G overcomes these issues by providing high bandwidth, low latency, high data rate, etc. The number of devices that the 5G network can handle is massive. The QoE of 5G is taken care of by the Quality of Service (QoS) parameters, which is high. But, to achieve high QoE in 5G the resource consumption is extremely high, so the cost involved is also high. To overcome this, we go for radio network aggregation for 5G mobile terminals, statistical delay bounded QoS driven, etc. For obtaining high data rate and low latency, we involve procedures like 5G cloud networks, Device to Device based relaying method for multicast services, etc. For high security, we employ the Frequency-Based 4GCRelative Authentication Model, etc. In the case of live streaming, we go for WiLiTV[11] that makes use of a fewer number of injection points but provides high QoE. We also address issues like network resource allocation, the transmission of Ultra High-Definition videos, etc. In this paper, we aim to address the factors that affect the QoE of the 5G network and the algorithms developed to overcome these issues.*

Key Words: Advanced technology, Base station, Latency, Throughput, QoE ,5G

1. INTRODUCTION

Wireless communication started in the early 1970s.The mobile wireless communication has emerged exponentially in the last four decades from first-generation to fourth generation. Fifth-generation technology offers extremely high bandwidth that users have never experienced before. Nowadays different wireless and mobile technologies are present such as third-generation mobile networks (UMTS universal mobile telecommunication system, cdma2000), LTE (long term evolution), Wi-Fi (IEEE 802.11 wireless networks), WiMAX[1] (IEEE 802.16 wireless and mobile networks), as well as sensor networks, or personal area networks (e.g., Bluetooth, Zigbee). Mobile terminals include a variety of interfaces like GSM which are based on circuit switching. All wireless and mobile networks implement that principle, that means all data and signaling will be transferred via IP (internet protocol) on the network layer. Fifth-generation technology provides various facilities like distant phone calls, a camera, mp3 and mp4 recording live telecast etc. The fifth generation is based on 4G technologies. These technologies offer miraculous data coverage and transmission with the available operating system of the mobile. The fifth generation will make a big difference in terms of quality and transmission over 4G. The fifth generation should be a more intelligent technology that interconnects the entire world without limits. This world opens new opportunity which has seamless working and functionality.

Section 2 of this paper contains the literature review of different papers addressing the different solutions for improving the Quality of Experience (QoE) of Video Streaming in 5G and their drawbacks. Section 3 of this paper contains the summary of the literature survey and talks about how OFDM is better than all these solutions. Section 4 concludes the pseudocode of Orthogonal Frequency Division Multiplexing (OFDM). Section 5 talks about the results obtained. Section 6 and 7 concludes the paper and shows some reference.

2. LITERATURE SURVEY

A) Provisioning an End-to-End QoS for VoIP over WiMAX network

In 3G and 3.5G wireless networks, simultaneous internet surfing and Voice over Internet Protocol (VoIP) are not feasible. The mobile WiMAX 4G[1] technology comes with improvised spectral efficiency and proposed Quality of Service (QoS) mechanisms are used. In this paper, we propose the multiple services flows for VoIP and Internet access by specifying QoS classification rules and associating the QoS to the proper DSCP value in the Internet Protocol (IP) network.

However, this paper has not explored the following topics: Resource utilization efficiency and network component capacity, priority inversion in queue management.

- In pre-provisional real-time Subframe (SF), there is a disadvantage of resource utilization, where not all the users go for VoIP services.

- In this case, dynamic SF would be advantageous where the real-time SF would be provided only during the VoIP services but is torn off once the VoIP service gets cut down.
- The next issue to be addressed is the priority inversion in the queue management of network elements.
- When there is no traffic congestion the queue implants First in and First Out (FIFO), however, sometimes, the burst traffic exceeds the link speed and the queue gets overflowed, leading to the loss of upcoming packets.
- When a low priority large packet passes through the queue, high priority, small upcoming packets are not able to pass through the network.

B) *Radio Network Aggregation for 5G Mobile Terminals in Heterogeneous Wireless Networks*

This paper [2] aims to provide the best QoS at the lowest cost for a given multimedia service by combining all the available wireless and mobile networks. The throughput is evaluated by using simulations with multimode mobile stations carrying multimedia traffic in heterogeneous environments with the coexistence of multiple Radio Access Technologies, such as 3G, 4G as well as future 5G radio access networks. They have proposed a basic 5G mobile terminal design based on radio network aggregation in the so-called Advanced mobile terminal with advanced QoS Routing algorithm which provides the highest multimedia access, throughput, and high user satisfaction with minimal cost per service and maximum utilization of network resources.

However, this module lacks in implementing the multi-interface heterogeneous wireless networks scenario.

C) Heterogeneous Statistical QoS Provisioning Over 5G Mobile Wireless Networks

Aims to propose [3] a basic heterogeneous statistical QoS provisioning architecture for 5G mobile networks by applying and extending the effective capacity theory. They efficiently apply the proposed architecture to implement 1) device to device network, 2) full-duplex networks and 3) cognitive networks for providing heterogeneous statistical delay-bounded QoS guarantee. This proposed architecture outperforms the existing statistical delay bounded QoS guarantee by maximizing the throughput.

D)State of the Art: Mobile Cloud Computing

This paper [4] aims at providing an insight on Mobile Cloud Computing along with 4G and 5G networks. It discusses some of the architectures, applications, advantages, and issues of Mobile cloud computing (MCC)

- Even now, battery lifetime, interaction latency, quality of service or experience, security, availability of seamless mobility, billing, etc. are yet to be resolved to MCC to reach its true potential.
- Even resource management and scheduling algorithms as well as virtualization of the 5G network remain unsolved.

E) Statistical-QoS Driven Energy-Efficiency Optimization Over Green 5G Mobile Wireless Networks

In this paper [5], a statistical delay-bounded QoS driven green power allocation scheme is developed which aims in maximizing the effective power efficiency which is the statistical QoS-guaranteed throughput (effective capacity) per unit power, over Single Input and Single Output (SISO) and Multiple Input and Multiple Output (MIMO) channels based 5G mobile networks. The experiment carried out the same and numerical results shown, tell us about enabling the effective implementation of green 5G wireless networks. The proposed EPE framework and developed QoS-driven green power allocation schemes aim in maximizing the EPE of SISO and MIMO channels under joint average and peak power constraints, which dominate other conditions.

However, this result is obtained for the energy-efficient homogenous statistical delay bounded QoS and is not applicable for heterogeneous statistical delay bounded QoS.

F) QoE in 5G Cloud Networks using Multimedia Services

This paper [6] aims in reducing the overall network delay, which is the main reason why we opt for 5G networks, by making use of the constant bit rate (VoIP) and variable bit rate (video) models. The proposed method also calculates the QoE for video streaming of the user based on the QoS parameters like delay and packet loss rate, which is shown to have outperformed the QoL method when played carefully with the QoS factors.

G) Novel D2D-Based Relaying Method for Multicast Services over 3GPP LTE-A Systems

In this paper [7], they aim to improve the multimedia multicast and sessions and transmissions among the User Equipment within an LTE-A-based network. They aim at improvising the throughput (high data rate and low latency) and by reducing the mean download time per user by delivering reliable connectivity to large numbers of UEs via proximity-based transmissions. The major benefits, when compared with the Conventional Multicast Scheme approach, are:

- The percentage of users that can download their data reaches around 100%.
- The throughput per user increases by 40%

Even though we observe a decrease in the download time, it is low as compared to the Conventional Multicast Scheme.

H) QoS Performances of heterogeneous Networks with Multiple Radio Access Technologies

This paper [8] represents the QoS framework for multiple Radio Access Technology (RAT)interfaces, in a heterogeneous network environment. It investigates QoS provisioning using vertical multihoming and multi-streaming in 5G multimedia networks, which leads to better performance with high QoS. This framework is user-centric handling multiple Radio Access Network (RAN) connections simultaneously and chooses the best out of them. Here they measure the QoS parameters under multiple RAN such as 3G, 4G, and 5G and use genetic algorithms and linear programming algorithms for resolving optimization problems and they achieve better performance for QoS parameters. The performance gain with the Advanced QoS-based User-centric Aggregation (AQUA) module increases with the number of heterogeneous nodes. In case of high traffic congestion, a linear programming algorithm in the AQUA module outperforms the genetic algorithm in the AQUA module.

The AQUA module is not able to dynamically choose the appropriate optimization algorithm for a heterogeneous network.

I)QoS-Aware Frequency-Based 4GCRelative Authentication

The existing LTE models with high broadband speed lack security mechanisms and provide service disruption due to time and bandwidth-consuming nature. This paper [9] aims in improving the security and service by employing the 4G+Relative authentication model (4G+RAM), which makes use of 2 independent protocols, namely:

- Privacy-protected evolved packet system authentication and key agreement protocol for the initial authentication.
- 4G plus frequency-based re-authentication protocol for the re-authentication of known and frequent users.

This approach minimizes signal loading, conceals the user identity to ensure privacy, and improves bandwidth consumption.

In this paper, the improvement of latency in terms of authentication time is not defined.

J) Optimal Video Streaming in Dense 5G Networks with D2D Communications

Global service providers aim at giving a QoE performance, for which D2D communication is being used in which there comes the problem of co-channel interference i.e., helper-requester pairs and cellular users. To resolve the same, we go for optimal rate allocation and description distribution for high-performance video streaming which achieves high QoE at high energy efficiency, limiting the co-channel interference [10]. They allocate optimal coding rates to different layers of video segments and packetize the video segments into multiple descriptions with forwarding error correction before transmission. They distribute the optimal number of descriptors to D2D helpers and base stations. This is done by implementing the genetic algorithm.

K) WiLiTV: Reducing Live Satellite TV Costs Using Wireless Relays

There is a high bandwidth requirement for the distribution of TV content due to the evolution of HDTV and UHDTV. The service providers are hence concentrating on developing new ways to reduce the cost and distribute the content with high penetration. In this paper, they have proposed cost-efficient wireless architecture [wireless live TV (WiLiTV)], consisting of a mix of wireless access technologies. In this live TV, content is infused into the network at certain locations, which contains some cellular base stations [11]. The content is then further distributed to other homes using a house-to-house Wi-Fi network or a 5G overlay. Here, they aim in giving the optimal content distribution with a minimal number of satellite injection points whereas preserving the same user experience provided by other conventional methods. This approach of WiLiTV involves a cost that is 60% lesser when compared to the conventional methods and is robust even in the case of link degradation. They have implemented the WiLiTV approach in 3 conditions: rural, suburban, and urban with varying time traffic and this approach has given optimal efficiency in rural areas. To find out the positioning of antennas and topology.

L) QoE-SDN APP: A Rate-guided QoE-aware SDN-APP for HTTP Adaptive Video Streaming

Video Service Providers are competing to provide the best QoE to their customers, for which Hypertext transfer protocol (HTTP) Adaptive Streaming comes as a solution to work around bottlenecks that cause Stallings. Not only on HAS but the QoE also depends on the Mobile Network Operators and on the network conditions. Software-Defined Networks are used to resolve this issue where VSPs and MNOs are separated allowing their network to open for more flexible, service-oriented programmability [12]. In this paper, they have developed a QoE-SDN App that enables the network exposure feedback from MNOs to VSPs towards the video segment selection in the context of HAS. Knapsack optimization is used for video selection and a Self-similar Least-Action Walk model is introduced to have segment caching. The QoE of video streaming users is improved by HAS applications running a mobility forecasting and rate estimation function within the MNOs domain. The QoE-SDN App has an impact on the revenues of MNOs which includes bandwidth savings and financial benefits. Thus, we can go for making this QoE-SDN App as a time-bound add-on feature or can be given to the customers based on their subscription type.

The SDN, MECs, and personalized network slicing technologies pose a challenge to net neutrality principles, whereas the QoE-SDN App provides an enhanced experience to the users, without posing any challenge based on net neutrality principles since this is based on the HAS context.

The paper has not explored the following.

- The real implementation of the QoE-SDN App must be carried out on an SDN testbed.
- Another concern is the scalability issue which is closely related to the placement of the SDN controllers.
- This paper concentrates only on the services provided by the HAS, whereas other areas are yet to be explored.

M) Optimized Video content delivery over 5G networks

The video consumption habits are exponentially increasing among mobile users, which results in high traffic on core networks [13]. This in turn deters the video quality and content delivery thus affecting the QoE. In this paper, specific solutions are discussed, to enable video traffic management, thus maximizing the QoE.

Drawbacks:

- Optimized virtual network functions for QoE management are still under development and virtual traffic management is also under progress, which is not discussed in the paper and delivers super high-quality video content.

N) 5G-QoE: QoE Modelling for Ultra-HD Video Streaming in 5G Networks

The two main expectations of 5G networks in video streaming are to handle Ultra High-Definition streaming quality and to meet high quality by QoE aware network management. In this paper, they propose a QoE prediction model that is accurate and is of low complexity which continuously monitors the quality of video applications [14]. The model provides the visional quality of UHD video application flows traversing a realistic multi-tenanted 5G mobile edge network testbed.

Using the above pseudocode, we have obtained the validation model to be like that of the training model.

- A QoE-aware video adaptation system that leverages the 5G-QoE framework to analyze and optimize likely user perception of quality for UHD video streams is still under development.
- It will inform decisions for smart traffic engineering, like when and which layers of a scalable video stream should be dropped in the network congestion to maximize benefit to network operations while minimizing the impact on perceived QoE.

O) Network Resource Allocation System for QoE-Aware Delivery of Media Services in 5G Networks

The 5G networks improve efficiency by dynamic network optimization to get high capacity and QoS. These networks will be based on Software Defined Networking and Network Function Virtualization, which enables self-management. In this paper [15], a network resource allocator system is proposed, which enables autonomous network management aware of the quality of experience (QoE). This system predicts the number of network resources to be allocated as well as the network topology setup required, which is done dynamically without impacting the QoS. It evaluates the system for live and on-demand dynamic adaptive streaming over HTTP and high-efficiency video coding services.

The Network Resource Allocator is engined by Machine Learning algorithms to predict traffic demands, translate them into specific operational thresholds, identify a topology to deliver incoming traffic according to an SLA and operational costs and, eventually, deploy it through the SDN controller. The Network Resource Allocator takes KPI measurements like path bandwidth and latency using G-Streamer players and network probes. The proposed Network Resource Allocator system is a reliable solution that addresses the problems for the flexible creation of an elastic network in an automated manner. Thus, it enables the controller to change the network topology instantiating or removing NFVs to forward the incoming traffic efficiently, removing the unused parts of a network to release these resources.

The paper has not explored the following.

- The HAS-specific QoE metrics such as initial delay, stalling time, number of quality switches, and inter switching times utilizing the eMOS scores coming from media players are yet to be added and candidate topology is to be considered based on the performance improvement and efficiency rate.

P) *Throughput Optimized Using Evolutionary Computing to Guarantee QoS in IEEE 802.16 Networks*

The WiMax network is currently used by major service providers, but WiMax does not provide implementation QoS policies. Even various scheduling mechanisms do not prove to be efficient for QoS provisioning due to improper synchronization of users. This paper [16] discusses the uplink scheduling that minimizes transmission error, buffer delay to provide efficient QoS provisioning. In this system, they go for the Orthogonal Frequency Division Multiplexing channel which is further divided into FDMA and TDMA. Both frequency range and the time slot are determined based on the application specific QoS requirement.
Here, 3 types of service classes are considered:

- Class A: it supports multimedia traffic, constant traffic, and CBR, the bandwidth is allocated in a fixed amount.
- Class B: it supports traffic for which guarantee of service is required for QoS, the bandwidth is decided for the corresponding connection based on the QoS and traffic arrival rate.
- Class C: it supports traffic for which guarantee of service is not required for QoS, the bandwidth is allocated only after Class A and Class B service classes.

In the uplink algorithm scenario, the data is transmitted from the subscriber station to the base station by using the FDMA/TDMA considering three classes of services namely.
Class A, Class B, and Class C and by the orthogonal frequency carrier modulation technique, where Class A has the high priority, Class C has the low priority and Class B contains the Delay Optimized Unit (DOU). Bandwidth allocation of the high priority connection affects the throughput of the low priority connections and, the improper user synchronization leads to the wastage of Bandwidth.
Thus, the above experiments are conducted to evaluate the performance of the proposed model over the existing model in terms of throughput and slot utilization performance which is shown to have improved by 12.72% and 11.72% respectively.

Q) *QoE-Aware Beamforming Design for Massive MIMO Heterogeneous Networks*

This paper [17] enlightens the problem of resource allocation based on the user's QoE in the downlink of a massive multiple input-multiple output heterogeneous network which consists of a macrocell base station equipped with a massive number of antennas. To maximize the user's QoE, a joint beamforming and power allocation scheme for Massive MIMO HetNets is used, where the beamforming vectors at the base station are designed based on the video and web browsing services. They aim in maximizing the mean opinion score under constraints on the BSs' powers and the required quality of service of the users. From the result obtained, we can infer that the more the number of antennas in base stations and the more the number of small cell antennas in the network, the higher is the user satisfaction. The optimization of the problem to determine beamforming vectors is by maximizing the mean opinion score (MOS) (i.e)

To solve this optimization problem, the below-specified algorithm is used.

R) *QoE-Assured 4K HTTP Live Streaming via Transient Segment Holding at Mobile Edge*

The internet and the TCP throughput become suboptimal in 4K live streams due to slow start and congestion control mechanisms, especially when the delivery path involves RAN. As a result, the mobile receiver's data rate may not meet the requirement of 4K streams, which in turn brings down the QoE. This paper [18] proposes the scheme edge-based transient holding of the live segment (ETHLE), which resolves the problem by performing context-aware transient holding of video segments at the mobile edge with virtualized content caching capability. This scheme can achieve uninterrupted 4K live streaming by holding the minimum number of live video segments at mobile edge, thus eliminating the buffer and the live stream latency. The conventional transport layer bottleneck is resolved by leveraging virtualized caching resources at the mobile edge. The ETHEL scheme can be flexibly deployed as a VNF (i.e., ETHEL edge) at the mobile network edge, which breaks the E2E content delivery path into two segments containing the RAN and the backhaul respectively at the application layer.

The benefits of such a strategy are threefold:

- First, it boosts TCP performance on both path segments without incurring the expensive computation overhead that a TCP split proxy has.
- Second, it enables the ETHLE edge to perform transient segment holding at the mobile edge.
- Third, it preserves the E2E content privacy/security since the ETHL Edge is owned and operated by the SMSP or CDN operator who rents virtualized computing and storage resources from MNOs.

S) *Hierarchical Caching for Statistical QoS Guaranteed Multimedia Transmissions over 5G Edge Computing Mobile Wireless Networks*

The caching-based content-centric edge computing network is an effective network architecture, which efficiently guarantees QoS for multimedia transmission over 5G

networks. However, the integration of network caching and edge computing for multimedia transmission over 5G has not been explored. This paper [19] proposes hierarchical-caching-based content-centric network architectures and their three different control mechanisms over 5G edge computing mobile multimedia wireless networks, to guarantee the statistical delay-bounded QoS for multimedia transmissions while minimizing redundant transmissions.
They have proposed 3 hierarchical edge caching mechanisms:

- Random hierarchical caching: it maximizes the average effective capacity, based on the user's request frequency.
- Proactive hierarchical caching: it maximizes the cache hitting rate by predicting the popularity of data contents and caching the data contents with high popularity nearby mobile users.
- Game-theory-based hierarchical caching: their three network caching tiers are formulated as three-game players in a cooperative game to maximize their aggregate effective capacity under the constraints of caching expenses at each tier.

They have considered different caching tiers of 5G edge computing:

- Caching in routers (tier 1)
- Caching in the cellular base station or Wi-Fi access point (tier 2)
- Caching in mobile devices (tier 3)

To overcome the disadvantages, the three caching mechanisms were developed, under different motivations with each mechanism integrating the three caching schemes in different tiers.

T) QoE-Based Resource Allocation for Multi-Cell NOMA Networks

The investigation on the resource allocation problem in multi-cell multicarrier non-orthogonal multiple access (MC-NOMA) networks is administrated to characterize the user-base station (BS) association, subchannel assignment, and power allocation. the target of the optimization problem formulated is to maximize the sum of Mean Opinion lots of the users within the networks. This challenge is solved by decomposing into two subproblems, which are characterized by combinational variables and continuous variables, where for the combinational subproblem, a 3-D matching problem is proposed for modeling the relationships among users, BSs, and subchannels, and then, a two-step approach is proposed to achieve a suboptimal solution and for the continual power allocation subproblem, the branch and bound approach is invoked to get the optimal solution [20]. it has been observed that the NOMA approach has significantly outperformed the OMA approach in terms of QoE and the fairness achieved is more within the case of the sum-MOS Maximization scheme.
As the algorithm designed was formulated combinatorial non-convex optimization problem of maximizing the sum MOS of the system. A general algorithm for the MOS model with various services like web browsing, voices, streaming audio, and video is yet to be explored.

U) CASH: Content- and Network-Context-Aware Streaming Over 5G HetNets

Heterogeneity is one amongst the most features that characterize the long run generation of cellular networks, 5G, etc. once we choose streaming high-quality, high bandwidth-consuming multimedia contents over bandwidth-constrained 5G heterogeneous networks (5G HetNets) there involves various challenges, including long video start time, video start failures, frequent buffering, and stalling, and caliber of experience (QoE) [21]. Conventional multimedia streaming technologies do not consider the network bandwidth or the interaction between the characteristics of the content and the resources. to cut back network strain and improve QoE, we propose ''Context-Aware Streaming over 5G HetNets (CASH)'' that helps to attain a tradeoff between content-context and network-context, through a multi-process technique. The CASH has an integrated architecture that consists of a media server, a flow scheduler, and one radio controller (SRC)

- The SRC and the user equipment (UE) together prepares a metadata file that's supported the network context.
- Then they access the metadata file from the SRC within the media preparation server, then analyze and cluster the contents supported the content context. The file is upgraded by accumulating the information of content-context.
- Then, the flow scheduler controls the flow of the clusters of the contents within the server-push mode and conveys that to the suitable radio access technology (RAT) conforming to the bitrate of the clusters and bandwidth delivered by RATs.
- Finally, the UE will aggregate the received packets and can playback the content.

In this paper, extensive simulations are administered to demonstrate the benefits of money over conventional methods in terms of peak rate, latency, users' experiences, and spectral efficiency.

This article presents CASH, a context-aware multimedia streaming scheme that allows high-quality video streaming over 5G HetNets by maintaining a trade-off between the available network bandwidth and the actual bitrate of various scenes of video content. The CASH offers far better QoE performance in terms of PSNR and MOS compared to the standard video streaming approaches and DASH, since it allocates the available resources supported content context. additionally, the CASH enables us to attain an enhanced network utilization in terms of saved bandwidth because the RAT of interest is nominated supported network context. supported theoretical analysis and extensive simulation results, the paper concludes that the integrated framework of content- and network-context-aware resource allocation is an efficient and smart approach for multimedia streaming over 5G HetNets.

3. OBSERVATIONS

S.No.	Problems to be addressed	Factors affecting the problem	Solutions
1.	Non-feasibility of simultaneous internet surfing and VoIP in 3G	Limited bandwidth Low Latency	Shifting towards WiMAX SG
2.	Requirement of high QoE in 5G multimedia networks	High resource deployment and high cost	Radio network aggregation in heterogeneous wireless network Statistical delay bounded QoS are driven by green power allocation.
3.	Buffering and low-quality video	Delay in the video streaming and low Bandwidth	5G cloud network using multimedia services. Device to a device-based relaying method for multicast services
4.	Live video streaming	High latency and Stallings	WiLiTV reduces satellite costs using wireless relays. Transient segment holding at mobile edge computing
5.	Security issues	Open nature of 5G networks	QoS-Aware Frequency-Based 4G+Relative Authentication Model
6.	Service disruption	time and bandwidth consuming nature of 5G	QoS-Aware Frequency-Based 4G+Relative Authentication Model

In compared all these mentioned methods of solution, Orthogonal Frequency Division Multiplexing is the effective and currently used technique in 4G as it can combat multipath interference with greater robustness and less complexity. An upgradation in the existing OFDM will pave a way for 5G as they will be using OFDM inspired waveform.

4. PSEUDOCODE

```
carrier = nrCarrierConfig;
carrier.NSizeGrid = 25;
carrier.SubcarrierSpacing = 15;
carrier.NSlot = 1;
carrier.NFrame = 0
csirs = nrCSIRSConfig;
csirs.CSIRSType = {'nzp','zp'};
csirs.CSIRSPeriod = {[5 1],[5 1]};
csirs.Density = {'one','one'};
csirs.RowNumber = [3 5];
csirs.SymbolLocations = {1,6};
csirs.SubcarrierLocations = {6,4};
csirs.NumRB = 25
powerCSIRS = 0;

disp(['CSI-RS power scaling: ' num2str(powerCSIRS) ' dB']);
sym = nrCSIRS(carrier,csirs);
csirsSym = sym*db2mag(powerCSIRS);
csirsInd = nrCSIRSIndices(carrier,csirs);
```

```
NumRB = carrier.NSizeGrid;
K = NumRB*12;
L = carrier.SymbolsPerSlot;
ports = max(csirs.NumCSIRSPorts
gridSize = [K L ports];

txGrid = complex(zeros(gridSize));
txGrid(csirsInd) = csirsSym;
plotGrid(gridSize,csirsInd,csirsSym);

gnb.NRB = NumRB;
gnb.SubcarrierSpacing = carrier.SubcarrierSpacing;
gnb.CyclicPrefix = carrier.CyclicPrefix;
OFDMInfo = hOFDMInfo(gnb);

txWaveform = hOFDMModulate(gnb,txGrid);
R = 4.
channel = nrTDLChannel;
channel.NumTransmitAntennas = ports;
channel.NumReceiveAntennas = R;
channel.DelayProfile = 'TDL-C';
channel.MaximumDopplerShift = 10;
channel.DelaySpread = 1e-8
chInfo = info(channel).

maxChDelay = ceil(max
(chInfo.PathDelays*channel.SampleRate)) +
chInfo.ChannelFilterDelay;
txWaveform = [txWaveform;
zeros(maxChDelay,size(txWaveform,2))];
[rxWaveform,pathGains] = channel(txWaveform);
pathFilters = getPathFilters(channel);
initialNSlot = carrier.NSlot;
SCS = carrier.SubcarrierSpacing;
H_actual = nrPerfectChannelEstimate(pathGains,
pathFilters,NumRB,SCS,initialNSlot);

SNRdB = 50;
SNR = 10^(SNRdB/20);
N0 = 1/(sqrt(2.0*R*double (OFDMInfo.Nfft))*SNR);
rng(0);
noise =
N0*complex(randn(size(rxWaveform)),randn(size(rxWavef
orm)));
rxWaveform = rxWaveform + noise
csirs.CSIRSPeriod = {[5 1],'off'};

refInd = nrCSIRSIndices(carrier,csirs);
offset = nrTimingEstimate(rxWaveform,
NumRB,SCS,initialNSlot,refInd,refSym)
rxWaveform = rxWaveform(1+offset:end,:);
rxGrid = hOFDMDemodulate(gnb,rxWaveform);
cdmLen = [2 1];
[H_est,nVar] =
nrChannelEstimate(rxGrid,refInd,refSym,'CDMLengths',cdm
Len);
estSNR = -10*log10(nVar);
disp(['estimated SNR = ' num2str(estSNR) ' dB'])
figure.
subplot (1,2,1)
imagesc(abs(H_est(:1,1)));
colorbar;
title ('Estimated Channel')
axis xy;

xlabel('OFDM Symbols');
ylabel('Subcarriers');

subplot (1,2,2)
imagesc(abs(H_actual(:1,1)));
colorbar;
title ('Actual Channel')
axis xy;
xlabel('OFDM Symbols');
ylabel('Subcarriers')
H_err = (H_est - H_actual(:,:,:,1:size(H_est,4)));
[minErr,maxErr] = bounds(abs(H_err),'all');
disp(['Absolute value of the channel estimation error is in the
range of [' num2str(minErr) ', ' num2str(maxErr) ']'])
function plotGrid(gridSize,csirsInd,csirsSym)

  figure()
  cmap = colormap(gcf);
  chpval = {20,2};
  chpscale = 0.25*length(cmap);

  tempSym = csirsSym;
  tempSym(tempSym ~= 0) = chpval{1};
  tempSym(tempSym == 0) = chpval{2};
  tempGrid = complex(zeros(gridSize));
  tempGrid(csirsInd) = tempSym;

  image(chpscale*tempGrid(:,:,1));
  axis xy;
  names = {'NZP CSI-RS','ZP CSI-RS'};
  clevels = chpscale*[chpval{:}];
  N = length(clevels);
  L = line(ones(N),ones(N),'LineWidth',8
  set(L,{'color'},mat2cell(cmap( min(1+clevels,length(cmap)
),:),ones(1,N),3));


  legend(names{:});

  title('Carrier Grid Containing CSI-RS')
  xlabel('OFDM Symbols');
  ylabel('Subcarriers');
end
```

5. RESULT

After running the OFDM code, we get the following output. Fig 1. shows the Carrier grid of Channel State Information Reference Signal (CSI-RS)

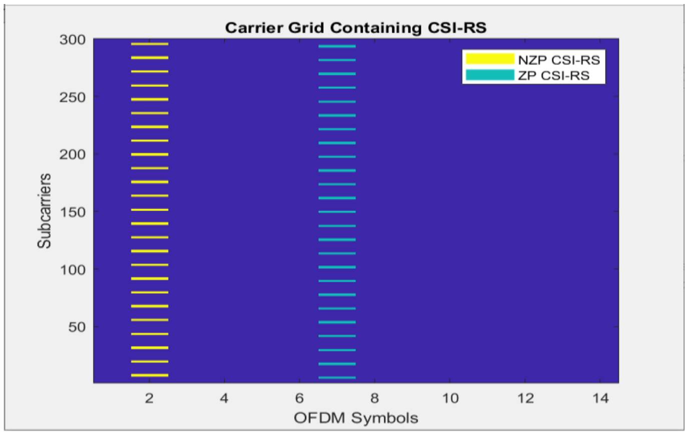

Fig 1: Carrier grid containing CSI-RS.

6. CONCLUSION

The development of mobile and wireless networks is going towards higher data rates and all-IP principles. Mobile terminals are obtaining each year more processing power, more memory onboard, and longer battery life for the same applications. 5G includes the latest technologies such as cognitive radio, SDR, nanotechnology, cloud computing, and based on the All-IP Platform. Thus, video streaming through 5G networks proves to be more efficient. The QoE of the end-users is high, which provides good quality video streaming, reduces buffering and delay, and produces user satisfaction. We have opted for the OFDM approach to solving the above-listed problems, as OFDM is very efficient and has good performance compared to the other solutions listed.

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