Anticipatory QoE Mechanisms in 5G Radio Intelligent Controller

Vidhya R., Karthik P.

Abstract—3GPP which is working on the 5G specification is also working on the NWDAF (Network Data Analytics Function) which is used for data collection and data analytics in a centralised manner in the 5G Core. ORAN (Open Radio Access Network) is also working on the Radio data collection entities for better handling of the Radio Resource Management which is termed as the Radio Intelligent Controller (RIC). The 5G Network elements and/or the OAM (Operations and Network Management) can decide how to use the data analytics provided by NWDAF and/or the RIC to improve the overall system performance. In this paper we show how to develop anticipatory QoE mechanisms by using the data available at the RIC and the NWDAF. We show that anticipatory AI functionality will help address QoE in a mobile video streaming use case.

Keywords—5G, Mobile Video Streaming, QoE, NWDAF

I. INTRODUCTION

As the 5G NR specifications takes shape in 3GPP, the focus is now on the 5G Core network components and how they can provide qualitatively different service environment for different services. 5G will be characterized by increasing number of service types, coexisting radio technologies and device types and as such a need for flexible end to end network/service orchestration capabilities will be crucial. A new network function, called Network Data Analytics Function (NWDAF) has been introduced in [1] which is anticipated to be used for data collection and data analytics in a centralized manner. Operators are expected to use this functionality for policy adjustments initially but the NWDAF functionality can grow based on specific usage that operators envisage. The NWDAF functionality is still growing and the specification is yet to see a final phase. Additional network control functions are expected to be added in subsequent releases. ORAN [9] is also working on the Radio data collection entities for better handling of the Radio Resource Management which is termed as the Radio Interface Controller (RIC). RIC is an acronym for RAN Intelligent Controller. The RIC will be used for customization in the RAN in support of fine grain network optimization to support emerging 5G NR use case environments. A few examples are provided in the following:

1. Industrial IoT: Orchestration of private 5G slice/namespace for businesses on industrial campus, Security services.
2. Connected Car: QoS enforcement to provide low latency, high bandwidth to vehicle applications.

3. Logistics, Tracking, Asset Management: Management of battery power of IoT devices.

This paper presents extensions to RIC and the NWDAF functionality to address the issues of QoE in 5G systems. As 5G is expected to support a host of service types, assured QoE across multiple users and service types is very important. QoE maintenance is also complex as it depends on a lot of parameter inputs which may not necessarily be available.

To handle qualitative aspects of user experience, in this paper we apply Fuzzy logic algorithms to deal with user experience factors. The QoS / KPIs are used along with user experience factors to address the issues of QoE. The fuzzy algorithms will also address issues of possible information uncertainty at the NWDAF level given that the evolving NWDAF specifications does not provide all possible information about the radio access network.

The key contributions of our paper are the following. We show how to use RIC / NWDAF to address QoE issues and address the specific issue of Video Streaming QoE. We show that anticipatory mechanisms are indeed necessary to address QoE.

A brief introduction to the 5G Core network is provided in the figure 1.

**Figure 1: 5G Core Network (Source: 3GPP TS 23.501)**

The key network functions in the 5G core networks of interest to us in this paper are the following:

• Policy Control function (PCF): This entity supports the policy framework for controlling the network behavior specifically it provides rules for the control plane functionality.

• The Session Management Function (SMF) supports selection and control of User Plane (UP) functions, and the User Plane Function (UPF) provides support for packet routing - forwarding, QoS handling for user plane and packet inspection and related policy control.
Anticipatory QoE Mechanisms in 5G Radio Intelligent Controller

- The Radio Congestion Awareness Function (RCAF) updates the PCF about congestion issues in the radio access network.
- The Network Exposure Function (NEF) provides APIs to applications / network servers to inform the network about their services requirements.
- The Network Slice Selection Function (NSSF) binds a UE with a specific network / functional slice.

NWDAF is a new 5G core network function[2]. The NWDAF achieves policy modifications (Supposedly in real time) based on the information available such as load levels per slice, so in effect the NWDAF provides slice specific network data analytics to the PCF and the NSSF over the interfaces Nnwdaf, Nnssf and Npcf [2]. PCF will use the NWDAF inputs for policy optimizations. The NSSF will utilize the NWDAF’s inputs to maintain the UE to slice mapping for the different data flow characteristics. The RIC has two components, the Near Real Time RIC that will reside close to the CU (Central Unit) and the Non Realtime RIC that typically resides at the Application level. The near real time RIC is shown in figure 2, this collects all the data from the gNBs to assist any possible RRM optimizations. The Near RT RIC gets the policy advice from the Non RT RIC.

A.QoE Definitions
The QoE definitions for 5G NR is still evolving in the 3GPP forum, the work is expected to progress in Release 17. We present a quick survey of recent QoE studies. Different mechanisms have been presented for obtaining QoE, for instance, the work presented in [3] investigates new architectures for QoE-driven resource control for long-term evolution (LTE) and LTE-advanced networks, including a selection of KPIs to be monitored in different network elements. A new QoE server has been described where the new QoE server is responsible for:
1. Collecting performance indicators from different network elements,
2. Estimating the QoE for specific data services from previous performance indicators,
3. Triggering potential actions (depending on the use case).

On the other hand, in [4] the QoE Influence Factors (IFs) are categorized into five dimensions:
1. Technology performance on four levels: application/service, server, network, and device;
2. Usability, referring to users’ behavior when using the technology;
3. Subjective evaluation;
4. Expectations; and
5. Context.

The EU Qualinet community lists the following QoE IFs:

- **Human IFs** present any time varying property and or the characteristic of a human user. Examples include demographic and socioeconomic backgrounds, the user’s emotional state (visual and auditory acuity, age, motivation, emotions).
- **System IFs** refer to the attributes that affect the technically produced quality of applications or service.
- **Context IFs** are the factors that capture the situational property and could cover a the user’s environment (physical, temporal, social, economic) and technical characteristics” (e.g. movements, time of day, privacy mode).

In summary the QoE definitions are qualitative and handling QoE requires Qualitative analysis solutions. To provide QoE solutions that address the issues of Human and Context IFs, we look at the below attributes for obtaining appropriate QoE objectives:
1. **Context**: defines the type of information considered to forecast the system evolution.
2. **Prediction**: specifies how the system evolution is forecast from the current and past context.
3. **Optimization**: describes how prediction is exploited to meet the application objectives.

It must be also noted that these attributes are also discussed in the literature under the “Anticipatory Networks” as mentioned in [5]. In this paper we use the network attributes available at the RIC / NWDAF to achieve the anticipatory Qoe objectives. Some of the attributes assumed at the RIC / NWDAF are derived attributes at the different 5G Radio Network nodes and the architecture facilitating the collection of all the required attributes at the RIC / NWDAF is not the subject of this paper. From a network QoE perspective, the context information that we use for the QoE analysis of video streaming are the following:

Figure 2: 5G Network Architecture with the ORAN RIC
Figure 3: The 5G NR gNB CU-CP with the ORAN RIC
1. Location Context, covering mobility (Space Time prediction) and Location patterns / trajectories.
2. Link Context which is the prediction of the evolution of the physical wireless channel and the combined Channel and mobility context.
3. Traffic Context covering traffic characterization and load.

1 and 2 above can be termed as the Channel-mobility context.

II. PROBLEM FORMULATION AND ANALYSIS

A. QoE analysis at RIC / NWDAF, idea and contribution

In this paper, we address the problem of QoE for video streaming in 5G networks. 5G networks are anticipated to handle not just conventional video streams but 360 degree video, AR/VR video streams as well. The objective is to be able to address the issue of QoE for Video streaming in a LTE/5G Heterogeneous network (Figure 4). The QoE is evaluated at the NWDAF node in the 4G/5G Network.

QoE analysis at the NWDAF has to deal with a vast amount of data collected at each network node and the UE. We need a mechanism to filter data at each node and pass it to NWDAF entity.

The two key video streaming parameters that will have to be controlled are the Video Rate and Freezing. Some of the parameters that affect Video Rate and Freezing are the Link Context (SINR, Bandwidth Availability), 5G cell availability, number of handover or switching between LTE and 5G termed as mobility context (as the 5G cells will be sparse in the initial deployment), the Traffic Context and the UE Context (Available Buffers etc) apart from the human factors (ex: tendency and frequency change in view angle). The above parameters are monitored and mapped to required video rates and possible Freezing probabilities to take corrective actions.

![Figure 4: The simulation setup](image)

In this paper we use two factors that affect video quality in a 5G network scenario

1. Combined channel and mobility context
2. Congestion (Traffic Context)
3. Human factors (Head tilt for view angle change)

B. Channel Mobility Context Prediction:

To find the Channel Mobility context, we use fuzzy logic to find the best candidate UEs that are likely to handover soon. It must be noted that the RIC / NWDAF is assumed to obtain the location information of the UEs through the location servers. These interfaces between the NWDAF and the Location servers are yet to be defined in the 3GPP specifications but are a potential input to the specifications in the future. We identify UEs that are far enough for the center of the cell and most likely to handover to another target cell soon. We identify the devices that are at cell boundary and calculate the handover possibility based on the differentreadings of their signal to noise ratio (SNR), radio distance(RD) and round-trip time (RTT).

We use a fuzzifier to quantize these parameters, the membership functions of inputs and its location decision functions are shown in the figure 5.

![Figure 5: The membership functions for Channel / Mobility Prediction](image)

The membership functions and the inference rules are motivated by the Base Station coverage and the radio distance that can be reached with the maximum allowed transmission power.

C. Calculation of the Congestion Level

Just as in the previous section we apply fuzzy logic to find the congestion levels in the system (4G/5G network).

We capture the Inter Packet Gaps (IPG) of the incoming packets into the network to qualify congestion, we term it as T_S and the packets exiting the 4G/5G network be T_C. In a congested network the Inter Packet Gaps will be dispersed. Which results in T_D being greater than T_S.

The measure of the network congestion is provided by the difference between T_C and T_S. The degree of congestion in the network is indicated by the extent of the difference.

The rate of data transfer from the application into the network, and the client receiving rate from the network are calculated as R_S and R_C, respectively, the difference between the two rates, R_D, can then be calculated as:

\[ R_D = R_S - R_C \]

The network congestion level, C_L, can subsequently be calculated as:

\[ C_L = \frac{R_D}{R_S} \]

The Delta C_L which represents the difference between the current and the previous values of C_L are calculated. The inference rules are based on the values of C_L and the Delta C_L are shown in Figure 6 and figure 7.
Anticipatory QoE Mechanisms in 5G Radio Intelligent Controller

Table 1: Percentage failure of packets in video clips (biased by mobility factor)

| Video Clip | Time Duration minutes | Percentage of failure packets | mobility factor (no. of 4G/5G Switches) |
|------------|------------------------|--------------------------------|----------------------------------------|
| Video Clip 1 | 1:32                  | 4.79%                        | 4                                      |
| Video Clip 2 | 1:27                  | 3.43%                        | 1                                      |
| Video Clip 3 | 1:06                  | 1.52%                        | 1                                      |
| Video Clip 4 | 1:54                  | 4.68%                        | 3                                      |
| Video Clip 5 | 1:26                  | 1.79%                        | 2                                      |
| Video Clip 6 | 1:32                  | 2.55%                        | 2                                      |
| Video Clip 7 | 1:43                  | 2.76%                        | 3                                      |
| Video Clip 8 | 1:21                  | 1.83%                        | 2                                      |
| Video Clip 9 | 1:17                  | 2.60%                        | 2                                      |
| Video Clip 10 | 1:07                  | 0.96%                        | 1                                      |

The figure 8 shows that as the correction lead time increases the QoE decreases.

III. CONCLUSIONS AND FUTURE WORK

In this paper, we developed a fuzzy logic mechanism to handle 360° video streaming for 4G/5G wireless deployments. We calculate the Channel/Mobility context and the traffic context, then combine them again using a set of fuzzy rules to calculate the needed data rates to effectively utilize the high bandwidth available in 5G and cope with high bandwidth volatility in a 4G/5G network scenario. The so-called Human IFs are still not accounted for in this work i.e. the user head tilt and its effects on the buffer flush at the client side will have to be accounted for. We provide a mechanism to calculate the optimal rate allocation between the 4G and the 5G cells and across the video base tier and enhancement tier. In heterogeneous 4G / 5G networks, it is evident that the 5G channel can be used in a cost-efficient manner to not just compensate for the low throughput in 4G cells but also retransmit chunks that cannot be delivered in time through 4G cells. Further work will focus on the RIC / NWDAF architecture for Realtime data collection from the network entities and video correction. Future work will also cover the development of a hierarchical fuzzy logic system to account for multiple levels of information granularity between the radio network nodes and the NWDAF entity.
REFERENCES

1. 3GPP TS 23.501, “System Architecture for the 5G System”, LTE Rel. 15, June 2018.
2. 3GPP TS 23.288, Architecture enhancements for 5G System (5GS) to support network data analytics services, version 16.0.0.
3. Alexander Raake Sebastian Moller, "Quality of Experience – Advanced Concepts, Applications and Methods", Springer, no. ISSN 2192-2810, 2014.
4. Ying Wang et al, A Data-Driven Architecture for Personalized QoE Management in 5G Wireless Networks, IEEE Wireless Communications - February 2017
5. N. Bui, S. Valentin, and J. Widmer, “Anticipatory quality-resource allocation for multi-user mobile video streaming,” in IEEE Workshop on Communication and Networking Techniques for Contemporary Video (CNCTV), 2015.
6. Wireless Big Data of Smart 5G, WWRF white paper 2, Outlook 20, November 2017
7. L. Breslau, P. Cao, L. Fan, G. Phillips, and S. Shenker, “Web caching and Zipf-like distributions: evidence and implications,” INFOCOM, March 1999.
8. M. Proebster, M. Kaschub, T. Werthmann, and S. Valentin, “Contextaware resource allocation for cellular wireless networks,” EURASIP Journal on Wireless Communications and Networking, vol. 2012, p.2012:216.
9. https://www.o-ran.org/
10. https://www.akamai.com/us/en/multimedia/documents/white-paper/bit-rate-and-business-model.pdf

AUTHORS PROFILE

Mrs. Vidhya R., is a research scholar in the Dept. of Telecommunication Engineering, at KSIT Bengaluru, affiliated to VTU. She completed his masters in VLSI and Embedded Systems Design, at VTU, Belagavi, India. She is a life member of ISTE and IEI.

Dr. P. Karthik, has received the PhD degree. He is presently working as Associate Professor at KSSEM, Bangalore. He has 7yrs of experience in teaching and has published papers in 4 International Journals, 3 International Conferences and 4 National Conferences. His academic excellence involve associating with other Institutions / Universities to conduct various activities like workshop, guest lecturer etc., he has motivated students to do mini projects and publishing papers. He has done about 15 journals and 30 conference research articles. His areas of specialization are Embedded Systems, Networks and Communication. He is a IEEE member.