QoE Management for 5G New Radio

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Abstract: Quality of Experience (QoE) is used to monitor the user experience of telecommunication services, which has been studied for a long time. In universal terrestrial radio access network (UTRAN), evolved UTRAN (E-UTRA) and Long Term Evolution (LTE), QoE has also been specified for the improvement of user experience. The 5G New Radio (NR) technology is designed for providing various types of new services, and therefore operators have strong demand to continuously upgrade the 5G network to provide sufficient and good QoE for corresponding services. With new emerging 5G services, 5G QoE management collection aims at specifying the mechanism to collect the experience parameters for the multimedia telephony service for IP multimedia subsystem (IMS), multimedia broadcast and multicast service (MBMS), virtual reality (VR), etc. Taking LTE QoE as a baseline, generic NR QoE management mechanisms for activation, deactivation, configuration, and reporting of QoE measurement are introduced in this paper. Additionally, some enhanced QoE features in NR are discussed, such as radio access network (RAN) overload handling, RAN-visible QoE, per-slice QoE measurement, radio-related measurement, and QoE continuity for mobility. This paper also introduces solutions to NR QoE, which concludes the progress of NR QoE in the 3rd Generation Partnership Project (3GPP).

Keywords: NR; QoE; measurement collection; activation; deactivation; mobility; RAN visible QoE; radio-related information

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1 Introduction

The multimedia services have experienced swift development over the past decades with more services, such as streaming services, virtual reality (VR), and extended reality (XR), coming to people's daily life. The emergence of various services, along with the convergence of multimedia communication, has brought more challenges to the radio access network (RAN), pushed the competition between network service providers, and aroused the user expectations of network services[1]. Quality of Experience (QoE) is used to reflect the quality experience of a user when he or she uses the telecommunication service. The definition of QoE in the 3rd Generation Partnership Project (3GPP) is "the collective effect of service performances which determines the degree of satisfaction of a user of a service"[2]. Since the 5G New Radio (NR) has been put into use, NR QoE is designed for different service types and complex scenarios. In December 2019, 3GPP started a study project for NR QoE with the description named "Study on NR QoE management and optimizations for diverse services"[3]. In February 2021, with many discussions, the study item of NR QoE has been completed and a new work item (WI) was started in May 2021 to specify the technical details of NR QoE solutions.

QoE has gained much attention in the research and industry area, not only in 3GPP. In 2019, a survey[4] of mobile edge caching was provided, with the demand for greater QoE and performance. In the same year, a paper[5] discussed some QoE improvement issues based on artificial intelligence technology. This paper mainly focuses on the progress in 3GPP.

The rest of the article is organized as follows. In Section 2, an overview of QoE is given. Section 3 introduces the basic solutions to NR QoE, such as the activation/deactivation procedures, the triggering and stopping of QoE, etc. In Section 4, some further solutions to NR QoE are discussed, such as handling in RAN overload, RAN visible QoE, radio-related information, per-slice QoE, etc. Section 5 concludes the paper.

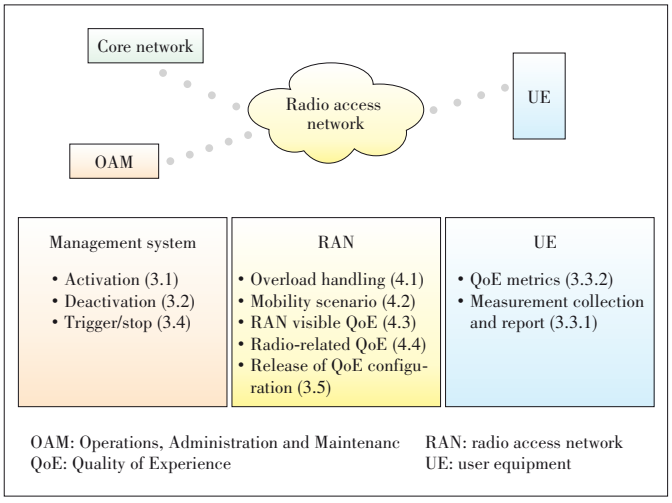
2 Overview

The QoE measurement collection for LTE has been specified in 3GPP. It is vital to guarantee the end users' experience, especially when the mobile network operators provide some real-time services which require high data rate and low latency, e.g. streaming services[6]. To support various new ser-

vice types and scenarios in 5G NR, the enhancement for QoE is discussed in Rel-17. NR QoE takes LTE QoE as a baseline. The main features of LTE QoE can be categorized into three parts as follows. The first is that both signaling based and management based cases are allowed. The second is that the LTE QoE feature is activated by trace function. The last is about the transfer of application layer measurement configuration and application layer measurements. To be specific, the application layer measurement configuration received from Operations, Administration and Maintenance (OAM) or core network (CN) can be encapsulated in a transparent container, which is forwarded to user equipment (UE) in a downlink radio resource control (RRC) message; the application layer measurements received from UE's higher layer can be encapsulated in a transparent container and sent to the network in an uplink RRC message[7].

NR QoE supports the functionality of application layer measurement collection, which could collect the application layer measurement results of diverse services. Since there have been more newly introduced service types provided by operators, the supported service types of QoE have also been expanded. The currently supported service types in NR QoE include streaming services[8], multimedia telephony service for IP Multimedia Subsystem (IMS) services[9], AR[10], multimedia broadcast and multicast service (MBMS)[11], and XR. Meanwhile, the support for additional service types is not precluded.

The potential solutions to NR QoE include some basic procedures, such as the activation and deactivation procedures, QoE measurement triggering and stopping, and the release of QoE measurement configuration. There are some additional solutions aside from the basic procedures, including QoE measurement handling at RAN overload, supports for mobility, RAN visible QoE measurement, radio-related measurement and information, and per-slice QoE measurement. The remaining of the paper would describe the QoE solutions and procedures in detail. The main QoE mechanisms are depicted in Fig. 1, based on the primary part which performs the mechanism.



▲Figure 1. Diagram for NR QoE mechanisms

3 Management Mechanisms for NR QoE Measurement Collection

3.1 Activation

The activation of NR QoE could be divided into two types: one is signaling-based activation, the other is management-based activation. The main difference between the two types is that, the signaling based activation is configured by OAM and triggered by the core network (CN), while the management-based activation is configured and triggered by OAM.

In signaling-based activation of QoE, specifically, OAM sends the QoE measurement configuration to CN, and it is CN to initiate the activation of QoE and to send the QoE measurement configuration to the new generation radio access network (NG-RAN) node. The NG-RAN node sends the QoE measurement configuration to the UE access stratum (AS) layer via RRC message. After receiving the QoE measurement configuration, the UE AS layer sends it to the UE APP layer.

In management-based activation, the OAM sends the QoE measurement configuration directly to the NG-RAN node, without the involvement of CN. The NG-RAN node would find multiple qualified UE or UE that meets the criteria for QoE measurement (e.g. area scope, application layer capability, service type, etc.). Then the NG-RAN node sends the QoE measurement configuration to the specific UE or multiple qualified UE via RRC message. The steps after that are similar to the signaling-based activation. The procedures for QoE activation are shown in Fig. 2.

Multiple simultaneous QoE measurements for UE could be supported, the details of the technique would be discussed in the normative phase, and whether each QoE measurement could be configured per service type will also be discussed then.

3.2 Deactivation

In accordance with the activation procedures, the deactivation of QoE could also be divided into signaling-based deactivation and management-based deactivation. Similarly, the signaling-based deactivation is configured by OAM and triggered by CN, while the management-based deactivation is configured and triggered by OAM.

In signaling-based deactivation, the OAM sends a deactivation indication to CN to configure the deactivation for QoE. After receiving the deactivation indication, the CN initiates the deactivation of QoE measurement and sends the deactivation indication to the NG-RAN node. The deactivation indication is used to indicate which QoE measurement is to be deactivated. After receiving the deactivation indication, the NG-RAN node sends the deactivation indication to the UE AS layer via RRC message, and the AS layer sends the deactivation indica-

tion to the UE APP layer.

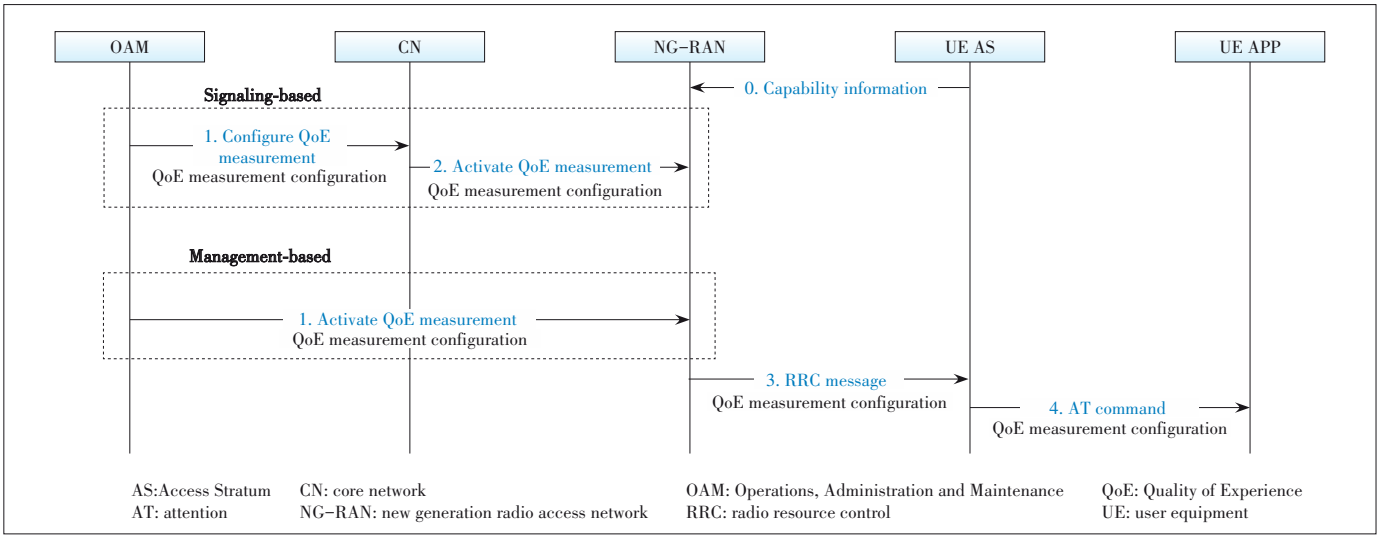
In management-based deactivation, the OAM configures the deactivation of QoE and sends the deactivation indication to the NG-RAN node directly without the involvement of CN. After receiving the deactivation indication from the OAM, the NG-RAN node sends the deactivation indication to UE AS layer via an RRC message. The following steps are similar to the signaling-based deactivation. The procedures for QoE deactivation are shown in Fig. 3.

3.3 QoE Measurement Reporting

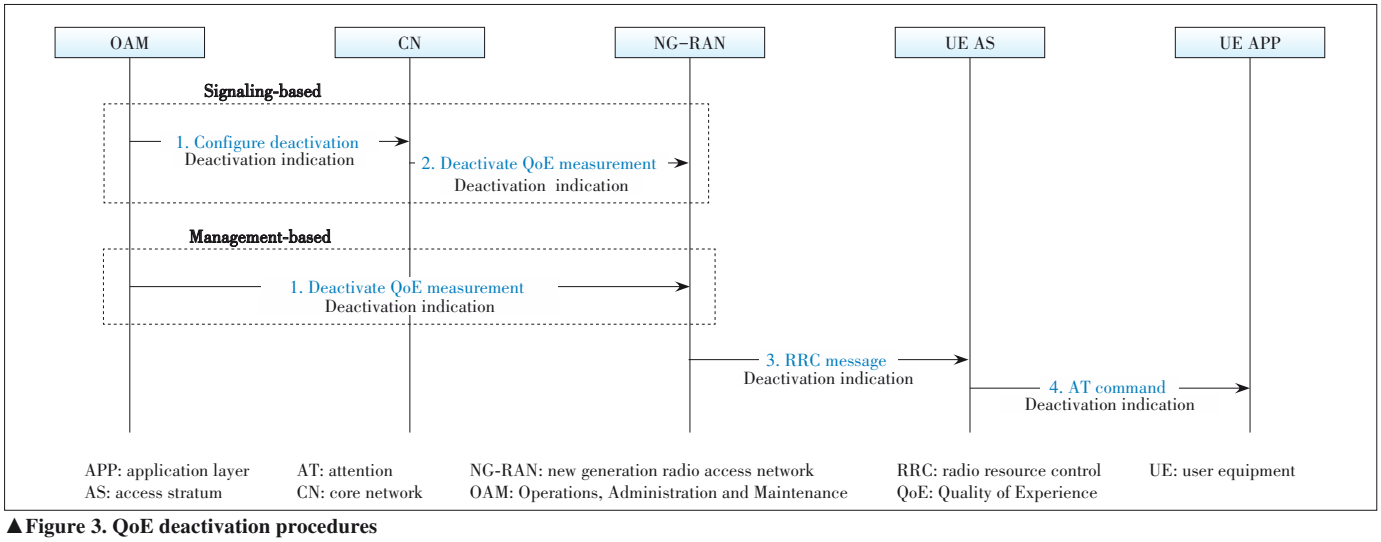
3.3.1 QoE Measurement Reporting Procedure

After receiving the QoE measurement configuration, the UE APP layer starts QoE measurement collection based on the configuration. UE APP layer generates the QoE reports according to the QoE measurement results, and once it is the time configured to report QoE measurement, the UE APP layer sends the QoE report to the UE AS layer. UE AS sends the QoE report to NG-RAN node via RRC message, and in particular, via a separate signalling radio bearer (SRB) aside from current SRBs. The separate SRB is used to differentiate the QoE report from other SRB transmissions, because the priority of the QoE report is lower than any other SRB transmission.

As stated in the overview, the QoE report sent via RRC message from UE's higher layer can be transparent containers with the measurement results encapsulated together. Hence, from the NG-RAN side, the contents in the QoE report container are totally transparent, i.e., the NG-RAN node is not able to get the QoE measurement results for the optimization of itself. Another discussion about RAN visible QoE, focusing on QoE measurement visible at the NG-RAN side, will be introduced in the next part of this paper. The NG-RAN node would send the QoE report container to the final destination configured by OAM, e.g., the trace collection entity (TCE) or measurement collection entity (MCE). The procedure is shown



▲Figure 2. QoE activation procedures



▲Figure 3. QoE deactivation procedures

in Fig. 4.

3.3.2 QoE Metrics

The QoE report is the result of a series of QoE metrics data collected by the UE. QoE metrics are valid for the quality of the supported services provided by the operators. Examples of some QoE metrics for MTSI[9] are provided in Table 1.

3.4 QoE Measurement Triggering and Stopping

It has been stated above that the activation and deactivation configurations are generated by OAM. Accordingly, the criteria for triggering and stopping QoE measurement are also configured by OAM. The currently approved criteria to realize the triggering and stopping of QoE are time-based and threshold-based criteria.

• Time-based criteria: When it is the configured time to trigger or stop the QoE measurement, the QoE measurement would be triggered or stopped. This is implemented by reusing the mechanisms for the start and stop of QoE specified in LTE. Fig. 5 depicts the time-based criteria.

• Threshold-based criteria: When the given thresholds to trigger or stop the QoE are passed, the QoE measurement would be triggered or stopped consequently. Fig. 6 depicts the threshold-based criteria.

3.5 Release of QoE Measurement Configuration

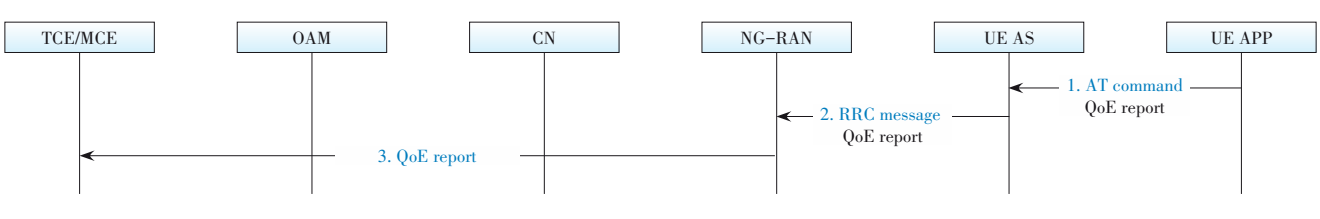
The QoE measurement collection and reporting would not last forever, i.e., the QoE measurement configuration for QoE measurement reporting should be released at some particular timing. The NG-RAN node has such ability to issue a release of QoE measurement configuration for UE, as long as the session for QoE measurement reporting is completed. In another case where UE hands over to a network that does not support QoE, RAN may need to release an ongoing QoE configuration.

4 Enhanced Features and Solution to NR QoE

4.1 QoE Measurement Handling at RAN Overload

Due to the extended bandwidth and various service types in 5G era, the RAN is confronted with more challenges to support the high burden of radio access. RAN overload, as depicted in Fig. 7, is an alarming problem that could probably happen, especially when QoE is supported, with extended pressure to transfer the QoE configuration and report.

Since RAN overload is an important situation, the reaction to RAN overload should not simply deactivate the QoE measurements. Instead, the QoE data information at RAN overload is necessary to be collected, and could be reported later to prevent aggravating the overload. In other words, it is vital to capture QoE data during periods of RAN overload. But on the other hand, persistent reporting might contribute to RAN overload[12]. Temporary stop and restart of QoE reporting could



▲Figure 4. QoE measurement reporting procedure

▼Table 1. Multimedia telephony service for IMS (MTSI) QoE metrics

QoE Metric	Description
Corruption duration metric	The time period from the NTP time of the last good frame before the corruption to the NPT time of the first subsequent good frame
Successive loss of RTP packets	The number of RTP packets lost in the successive per media channel
Frame rate	The playback frame rate is equal to the number of frames displayed during the measurement resolution period divided by the time duration (in seconds) of the measurement resolution period
Jitter duration	Jitter happens when the absolute difference between the actual playback time and the expected playback time is larger than JitterThreshold milliseconds
Sync loss duration	Sync loss happens when the absolute difference between value A and value B is larger than SyncThreshold milliseconds
Round-trip time	The RTT consists of the RTP-level round-trip time, plus the additional two-way delay due to buffering and other processing in each client
Average codec bitrate	The bitrate is used for coding "active" media information during the measurement resolution period
Codec information	The codec information metrics contain details of the media codec settings used in the receiving direction during the measurement resolution period

NTP: network time protocol QoE: Quality of Experience RTP: real-time transport protocol RTT: round-trip time

be useful functionality to handle RAN overload.

At the current stage, as shown in Fig. 8, RAN could take actions in the following three aspects to handle RAN overload:

- Stop new QoE measurement configurations
- Release existing QoE measurement configurations
- Pause QoE measurement reporting.

A specific diagram for procedures of RAN pausing the QoE reporting is shown in Fig. 9. Firstly, when RAN detects overload, it should send a request to UE AS to pause the QoE reporting. After that, RAN should send an indication to the management system about the temporary stop of the QoE report. When UE AS receives the request, it should inform the UE APP to temporarily stop the QoE reporting. After the RAN overload issue has eased off, RAN could resume the QoE measurement reporting that has been paused, indicating the UE to send the stored QoE report during the RAN overload.

Future works will focus on the detailed technical specifications of the pause/resume mechanisms, including whether to pause/resume for all QoE reports or per-QoE configuration, the time limit for UE to store the QoE reports, the limit for the stored report size, etc.

4.2 Support for Mobility

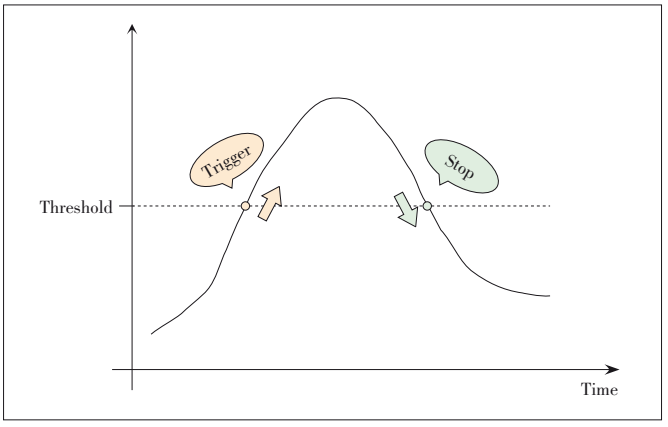
4.2.1 Intra-System Intra-RAT Mobility

With the development of modern traffic such as shared bikes, subway and high-speed railways, it is easier for people to move from one spot to another. Based on that consideration, the mobility scenario is a feature that should be enhanced in NR QoE. In the normative phase of Rel-17, the QoE continuity of intra-RAT mobility would be specified, to enable measurement of the impact of the mobility on the application and users' QoE. The intra-system intra-RAT mobility scenarios are categorized into intra-node and inter-node scenarios depicted in Figs. 10(a) and 10(b).

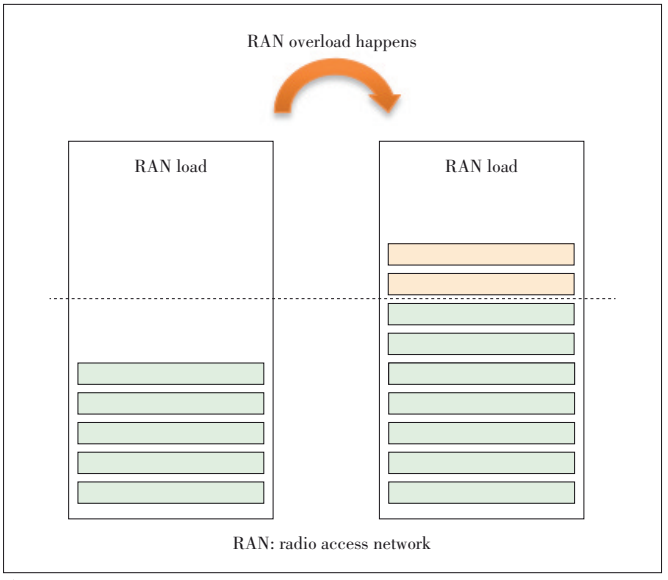
For the intra-node mobility scenario, the QoE measurement reporting for signaling-based and management-based QoE should both be supported. No matter before or after the UE handover, the served NG-RAN node is the same. Hence, there is no need to consider how to transfer the QoE measurement configuration from the source to the target. Both signaling-based and management-based QoE could be supported without much difficulty.

For the inter-node mobility scenario, UE

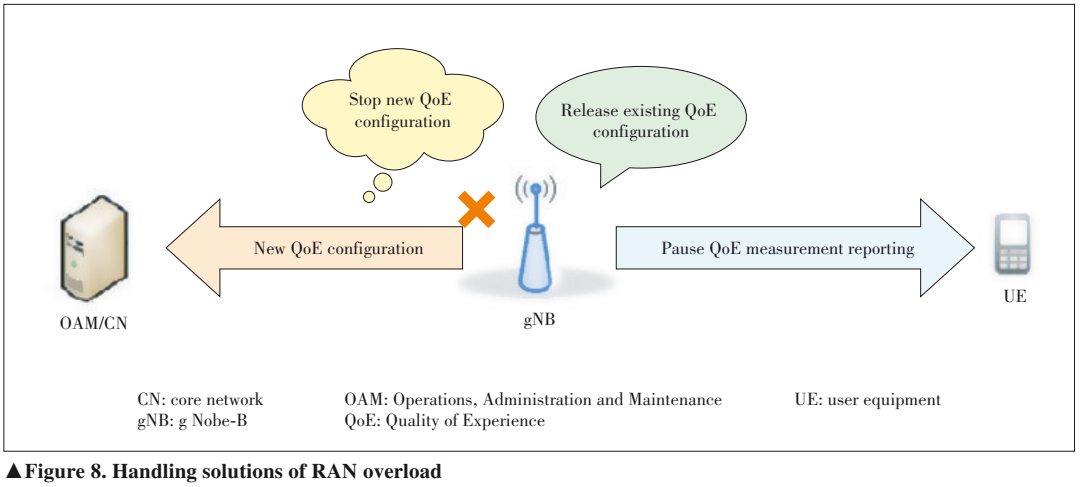
▲Figure 5. Time-based criteria



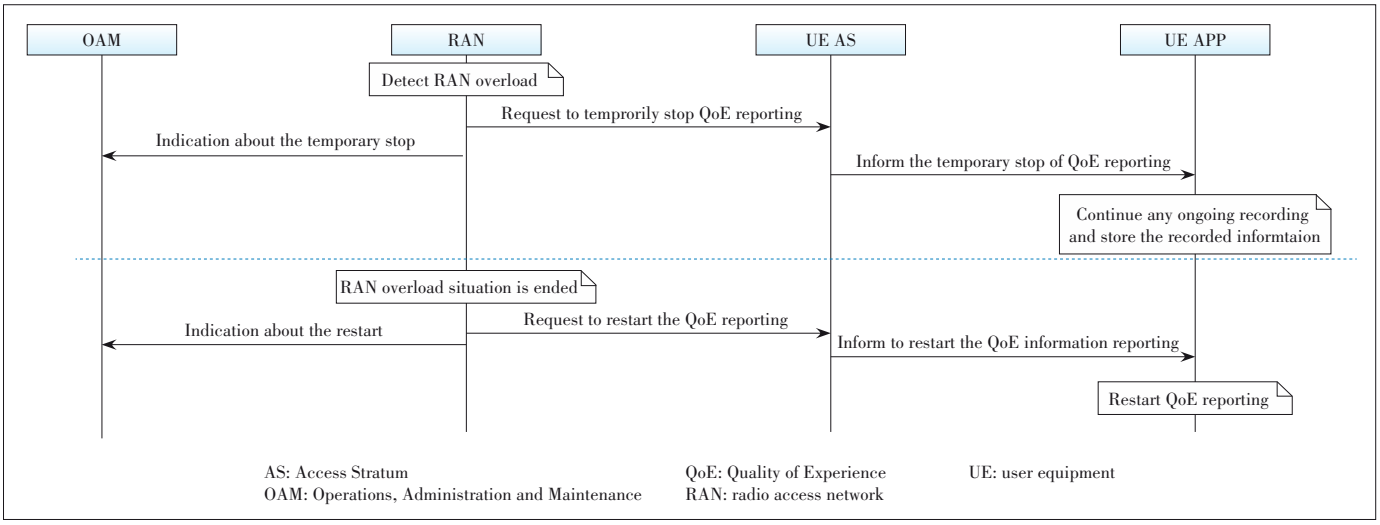
▲Figure 6. Threshold-based criteria



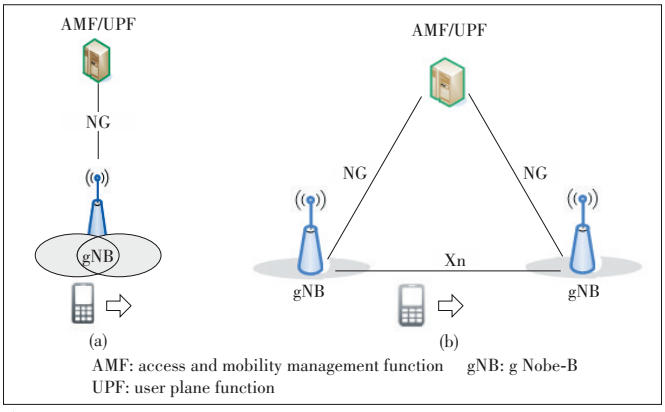
▲Figure 7. RAN overload



▲Figure 8. Handling solutions of RAN overload



▲Figure 9. Procedure of handling solutions to RAN overload



▲Figure 10. (a) Intra-node mobility and (b) inter-node mobility

hands over from the source NG-RAN node to the target NG-RAN node. In the case of signaling based QoE, CN can get the QoE measurement configuration, so that the QoE measurement could be transferred by the CN from the source NG-RAN node to the target NG-RAN node via NG interface. In the case of management-based QoE, the CN is not able to get the QoE measurement configuration, which makes it more complicated to transfer the configuration from OAM. Therefore, for the inter-node mobility scenarios, at least signaling-based QoE should be supported, while management-based QoE is to be studied in the normative phase.

The inter-system and inter-RAT mobility would be deprioritized in Rel-17.

4.2.2 Supported RRC State

In NR, the mobility for QoE measurements in RRC_CONNECTED state should be supported. As mentioned in the overview that NR QoE takes LTE QoE as a baseline, which uses the trace function to activate the QoE feature. To support mobility for UE RRC_CONNECTED, the trace function is also utilized in NR QoE. To be specific, the QoE measurement is transferred via the Xn and NG interfaces, with the part of UE application layer measurement configuration IE inside the Trace Activation IE.

QoE measurements in RRC_INACTIVE and RRC_IDLE state could be supported for multicast and broadcast service (MBS). To keep the QoE measurement configuration in RRC_INACTIVTAE state mobility, the UE could fetch the QoE measurement configuration from the node that hosts the UE context. Whether the QoE measurement configuration will be saved after UE goes to RRC_INACTIVATE state is still not decided. Once UE goes back to RRC_CONNECTED state, the QoE measurement configuration which has been stored when UE moves to RRC_INATCIVATE state might be useful. However, the necessity of doing this has not been confirmed.

4.2.3 Area Handling

There are some requirements that push the design of solutions for area handling. These requirements indicate that both the network side and the UE side could have the ability to check the UEs' location for a specific area requested for QoE measurement collection, which is called geographical filtering[6, 9]. But one thing to be noted is that if the network side is configured with geographical filtering, the related configuration should not be included in the QoE measurement configuration.

Based on the requirements, there are three possible solutions for area handling:

1) The network is responsible for keeping track of whether the UE is inside or outside the area and configures/releases configuration accordingly.

2) The network is responsible for keeping track of whether the UE is inside or outside the area, and the UE is responsible for the managing and start/stop of QoE accordingly.

3) The UE is responsible for area checking (UE has the area configuration) and the managing and start/stop of QoE accordingly.

4.3 RAN Visible QoE

As QoE measurements are transferred as a transparent container to the RAN side, the NG-RAN node cannot get the contents in the QoE measurement report. However, there are cases where RAN is in need of the QoE measurement results (e.g., buffer level) for the optimizations of itself. The QoE measurement information required by RAN could be designed to be visible to the RAN node, which is the so-called RAN visible QoE information.

The QoE metrics which could be visible to RAN are called RAN visible QoE metrics. The RAN visible QoE metrics for the streaming service could be round-trip time, jitter duration, corruption duration, average throughput, initial playout delay, device information, rendered viewports, codec information, etc.[13].

The message flow of RAN visible QoE information reporting is shown in Fig. 11.

1) The NG-RAN node sends the RAN visible QoE configuration to the UE, which may be sent along with the QoE measurement configuration.

2) The UE receives the RAN visible QoE configuration and/or the QoE measurement configuration. The UE collects QoE measurement results according to the received configuration and provides the RAN visible QoE report, along with the QoE report container to the RAN.

3) The NG-RAN node reads the RAN visible QoE report and/or forwards the QoE report container to the QoE server accordingly.

4.4 Radio-Related Measurement and Information

Since the radio-related measurement technology like MDT has been specified in 5G NR, it is possible that NR QoE could bring the existing mechanisms to do some optimization. Radio-related measurements and information are accordingly taken into consideration in NR QoE.

Radio-related measurements are measurements on the radio layer, with the purpose of helping networks to further evaluate and improve the QoE. The RAN can trigger radio-related measurement towards certain UE, based on the measurement configuration from the OAM.

Radio-related measurements are strongly associated with MDT mechanisms in several aspects. Firstly, radio-related measurements could be triggered by using existing mechanisms such as the MDT procedure. Secondly, the collection of radio-related measurements could also be done with the support of MDT[14]. Furthermore, the reporting of radio-related measurement is for all types of services that are supported, which include MDT-like measurements and additional measurements related to radio interface. If new radio-related measurements corresponding to currently specified MDT measurements are required for NR QoE management, these additional radio-related measurements will be specified as a part of MDT measurements.

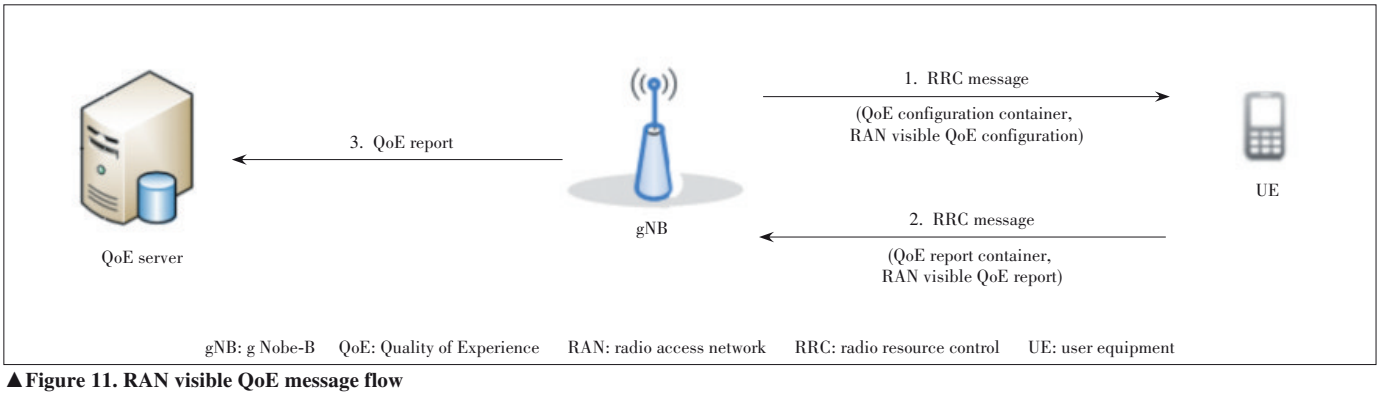
There are some further requirements for radio-related measurements, with respect to application-related measurements. Application-related measurements are only collected when the application is ongoing. Based on this fact, if the radio-related measurements are used for assisting application-related QoE measurements, it is beneficial and efficient if the measurement collection and reporting could start at the same time. If they are configured together, e.g. using the same trace function, or based on timestamps, correlation of the results could be done by post processing[15].

Radio-related information is information other than radio-related measurements, e.g., feature information, mobility history information, or dual connectivity status. Radio-related information may also be collected and reported, aside from radio-related measurements. Radio-related information may even be reported when radio-related measurements are not triggered over the radio.

One important requirement for radio-related measurement and radio-related information is that, both of them should be aligned and correlated with the QoE report, if they are reported. For example, trace ID could be used to align them with the QoE report.

4.5 Per-Slice QoE

With the application of slicing, the same service type could use different slices. Therefore, QoE measurements for each service type are not enough for the QoE management, while per-slice QoE is needed.



▲Figure 11. RAN visible QoE message flow

As shown in Fig. 12, there are three scenarios concerned by 3GPP at the current stage[16]:

· Scenario 1: different service types using different slices (e. g., UE1 & UE2)

· Scenario 2: different service types using the same slice (e. g., UE 1 & UE3)

· Scenario 3: the same service type using different slices (e. g., UE2 & UE3).

Three solutions[16] are approved for per-slice QoE measurement, with details left to be discussed in the future.

Solution 1: RAN is responsible for mapping slice scope to protocol data unit (PDU) session list. After UE sends the report with Slice ID, RAN could remap the PDU session ID back to Slice ID. The whole procedure is shown in Fig. 13.

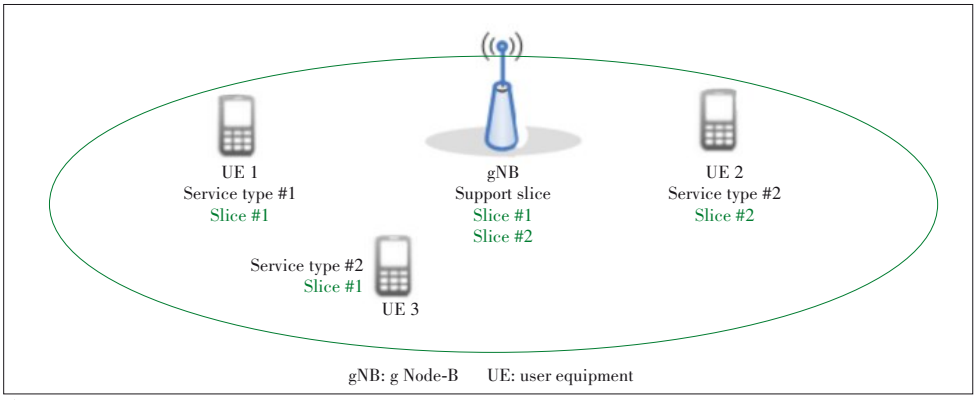
Solution 2: UE is responsible for mapping Slice Scope to QoE report. Whether the application layer or AS layer performs the mapping can be discussed at the normative stage. The whole procedure is shown in Fig. 14.

Solution 3: RAN is responsible for mapping the Slice ID to QoE measurements, with the Slice ID included in the QoE measurement configuration. The whole procedure is shown in Fig. 15.

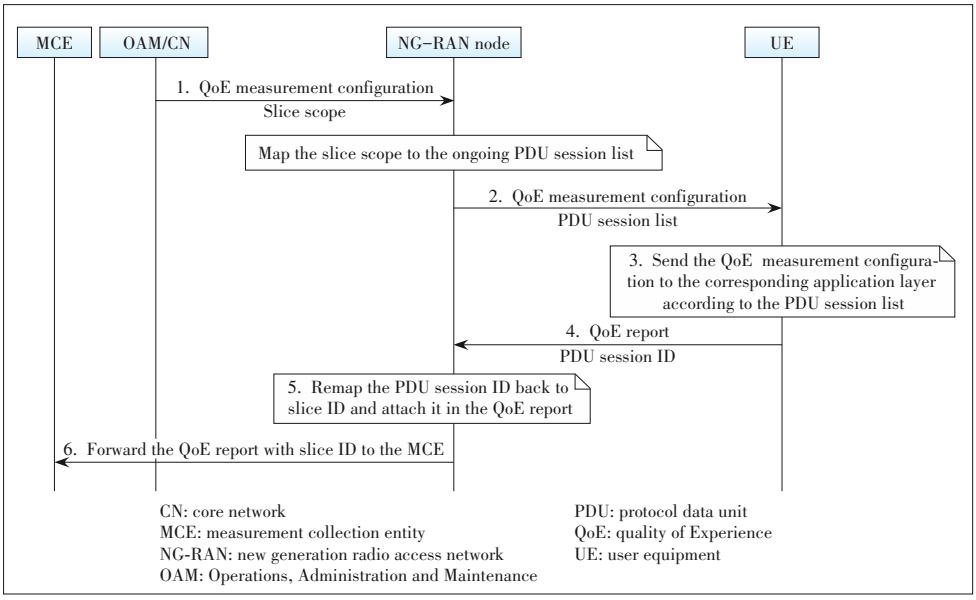
For all solutions mentioned above, Slice Scope is outside the QoE configuration container. When it comes to the mobility scenario, for signaling-based QoE, Slice Scope (e.g. list of single-network slice selection assistance information) should be transmitted to the target gNB during mobility. For management-based QoE, Slice Scope can be clarified at the normative stage.

5 Conclusions

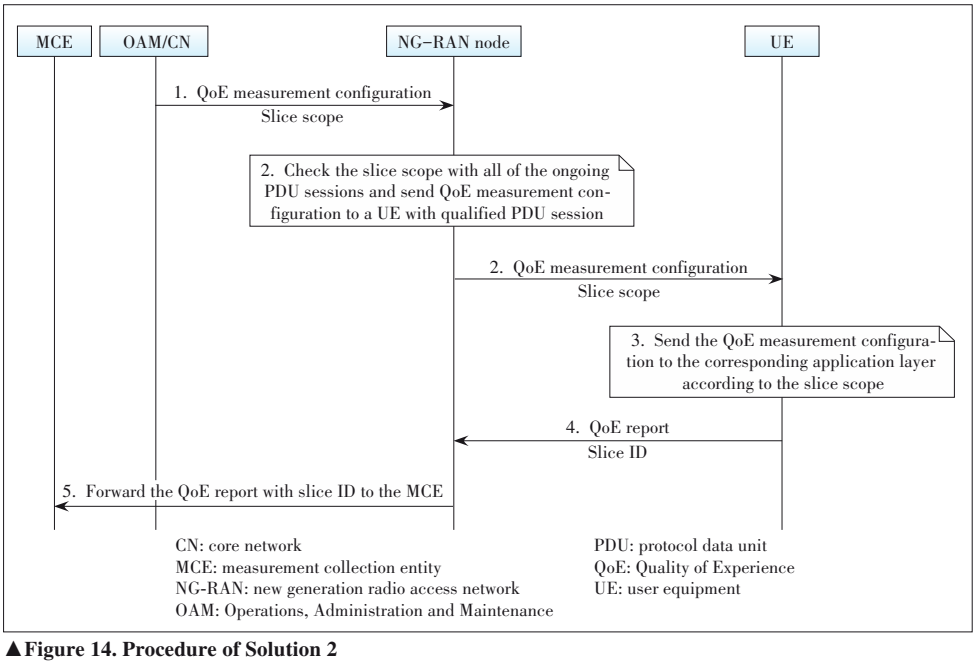
This paper provides the current



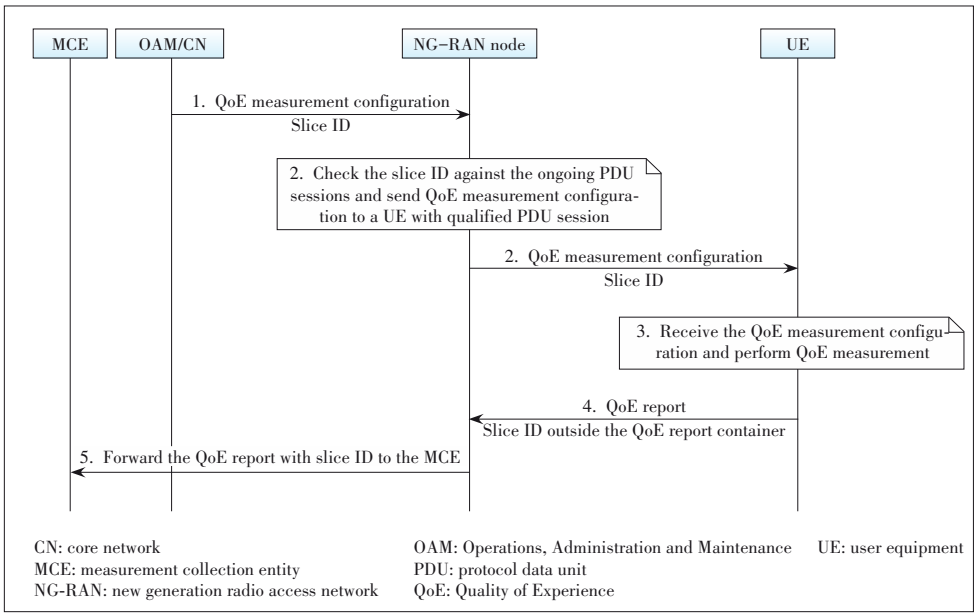
▲Figure 12. An example of different scenarios



▲Figure 13. Procedure of Solution 1



▲Figure 14. Procedure of Solution 2



▲**Figure 15. Procedure of Solution 3**

process of NR QoE from the perspective of various solutions agreed at 3GPP, which are divided into basic and additional solutions. The basic solutions and procedures include activation and deactivation of QoE, QoE measurement reporting, triggering and stopping, release of QoE measurement configuration, and QoE measurement handling at RAN overload. The additional solutions mainly contain the NR QoE mobility support, RAN visible QoE, radio-related measurement and information, and per-slice QoE. Further details of these solutions will be discussed in the future.

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