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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Multimedia Quality of Service and performance – Generic and user-related aspects

Assessment of the LTE circuit switched fall back – Impact on voice quality of service

Recommendation ITU-T G.1028.2

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Recommendation ITU-T G.1028.2

Assessment of the LTE circuit switched fall back – Impact on voice quality of service

Summary

While the long term evolution (LTE) circuit switched fall back (CSFB) can be considered as a separate procedure from voice service delivery over LTE, it has an impact on the quality of service (QoS) for the voice services and is therefore worthy of attention and consideration. Indeed, operators have to make sure that clients purchasing LTE-capable devices must keep the level of QoS they are accustomed to when compared with their former 2G and 3G devices, even when VoLTE is unavailable (for any reason, such as, networkor device). Therefore, specific and complementary key performance indicators (KPIs) are proposed in this Recommendation, together with procedures for their assessment.

It should be noted that this Recommendation focuses only on the specific impact of CSFB. The information it contains must be considered as a complement to provisions already defined in Recommendation ITU-T G.1028.

History

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Keywords

Circuit switched fall back, CSFB, LTE, quality of service, QoS, telephony, voice, VoLTE, 4G.

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Introduction

In early deployments of the fourth generation of mobile networks (LTE), it can happen that the delivery of multimedia services, and in particular voice over LTE (referred to in this Recommendation as VoLTE), is not possible by using a complete LTE infrastructure (with full IMS). This situation can remain applicable in the short and even medium term.

In the meantime pending the deployment of VoLTE, operators must use the legacy networks (using 2G and 3G technologies) when there is a need for voice and SMS delivery to LTE users.

The alternative to this issue is the use of CSFB, an interim solution allowing the usage of legacy networks, until full support for VoLTE is available.

Recommendation ITU-T G.1028.2

Assessment of the LTE circuit switched fall back – Impact on voice quality of service

1 Scope

This Recommendation provides guidance for assessment and measurement of the impact of LTE circuit switched fall back on QoS for voice services and provides means to express it in numerical terms, complementing provisions already defined in [ITU-T G.1028]. This Recommendation applies to voice service only.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.1028] Recommendation ITU-T G.1028 (2019), *End-to-end quality of service for voice over 4G mobile networks*.

[ETSI TR 103 219] ETSI TR 103 219 (2015), *Speech and multimedia Transmission Quality (STQ); Quality of Service aspects of voice communication in an LTE environment*.

[ETSI TS 123 272] ETSI TS 123 272 (2018), *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; Circuit Switched (CS) fallback in Evolved Packet System (EPS); Stage 2*.

3 Definitions

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BSS Base Station System

CS Circuit Switched

CSFB Circuit Switched Fall Back

E-UTRAN Evolved Universal Mobile Telecommunication System Terrestrial Access Network

GERAN GSM EDGE Radio Access Network

GPRS General Packet Radio Service

GSM Global System for Mobile

HO Hand Over

IMEI International Mobile Equipment Identity

IMS IP Multimedia Subsystem

IMSI	International Mobile Subscriber Identity
KPI	Key Performance Indicator
LCS	Location Services
LTE	Long Term Evolution of mobile telecommunications networks
MME	Mobility Management Entity
MOS-LQ	Mean Opinion Score, Listening Quality
MSC	Mobile Switching Centre
NB	Narrow Band
PGW	Packet Data Network Gateway
QoS	Quality of Service
RAT	Radio Access Technology
RF	Radio Frequency
RRC	Radio Resource Control
RNS	Radio Network System
SGSN	Serving GPRS Support Node
SGW	Serving Gateway
SIB	System Information Block
SMS	Short Message Service
SWB	Super Wideband
UDI	Unique Device Identification
UE	User Equipment
UMTS	Universal Mobile Telecommunications Service
USSD	Unstructured Supplementary Service Data
UTRAN	UMTS Terrestrial Radio Access Network
VoLTE	Voice over LTE
WB	Wide Band

5 Conventions

None.

6 Overview of CSFB

CSFB is a set of procedures, defined by technological standards [ETSI TS 123 272], that allow UEs connected to LTE cellular networks without access to VoLTE services, to have access to circuit switched services (such as voice, CS UDI video, LCS, USSD) through a temporary (i.e., for the duration of the usage of the concerned service) fallback from E-UTRAN (4G) to UTRAN (3G) or GERAN (2G) circuit switched (CS) domains, assuming that an overlapping coverage of 4G and 3G/2G is available. This fallback means that the voice call is not active in LTE, but in 3G or 2G.

Naturally, CSFB is only possible when users are using dual mode devices, i.e., able to operate both in LTE and UMTS or GSM networks.

To support CSFB, specific interfaces are necessary to connect the equipment in charge of call processing in these technologies. In particular, Figure 1 shows SGs (connecting the mobility management entity (MME) to the mobile switching centre (MSC)) and S3 (between MME and serving GPRS support node (SGSN)) interfaces, i.e., the ones that allow a practical implementation of the CSFB procedure. These interfaces correspond to interface C3 in [ITU-T G.1028] (see clause 10.1.3).

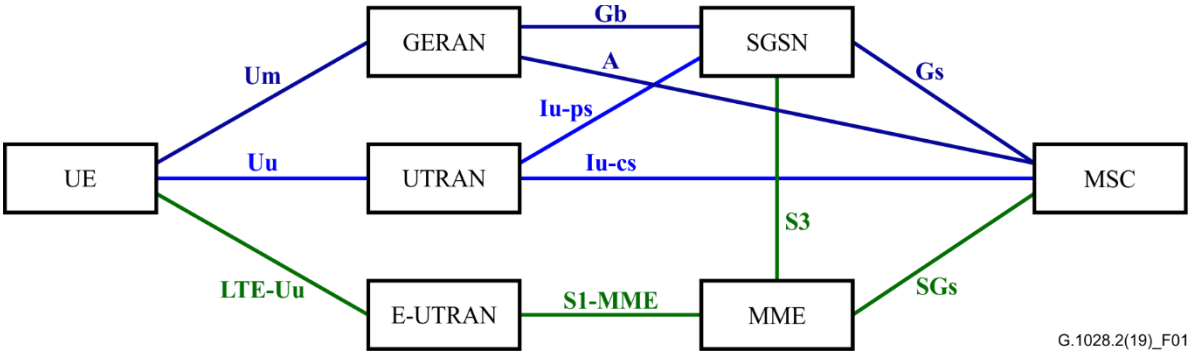

Figure 1 – Network interfaces required for handling of CSFB procedures

Once CSFB has been successfully completed, both user and signalling plans corresponding to the current service session will be handled as in UTRAN or GERAN CS domains.

Since this Recommendation focuses on CSFB impacts on voice service, the scope of discussion is limited to the aspects related to voice. It is also important to note that the transmission of SMS from/to UEs connected to E-UTRAN does not require a CSFB procedure and as such is not covered in this Recommendation.

CSFB is of particular importance in all LTE networks where IP multimedia subsystem (IMS) core network or VoLTE is not available (either because they are not supported by the user equipment (UE) or by the network), since it is the only way UEs can access CS services, and in particular a critical one such as voice.

Figures 1 to 3 (extracted from [ETSI TS 123 272]) represent the corresponding signalling flowcharts between these interfaces (respectively for a mobile originating context in Figure 2 and for a mobile terminating context in Figure 3).

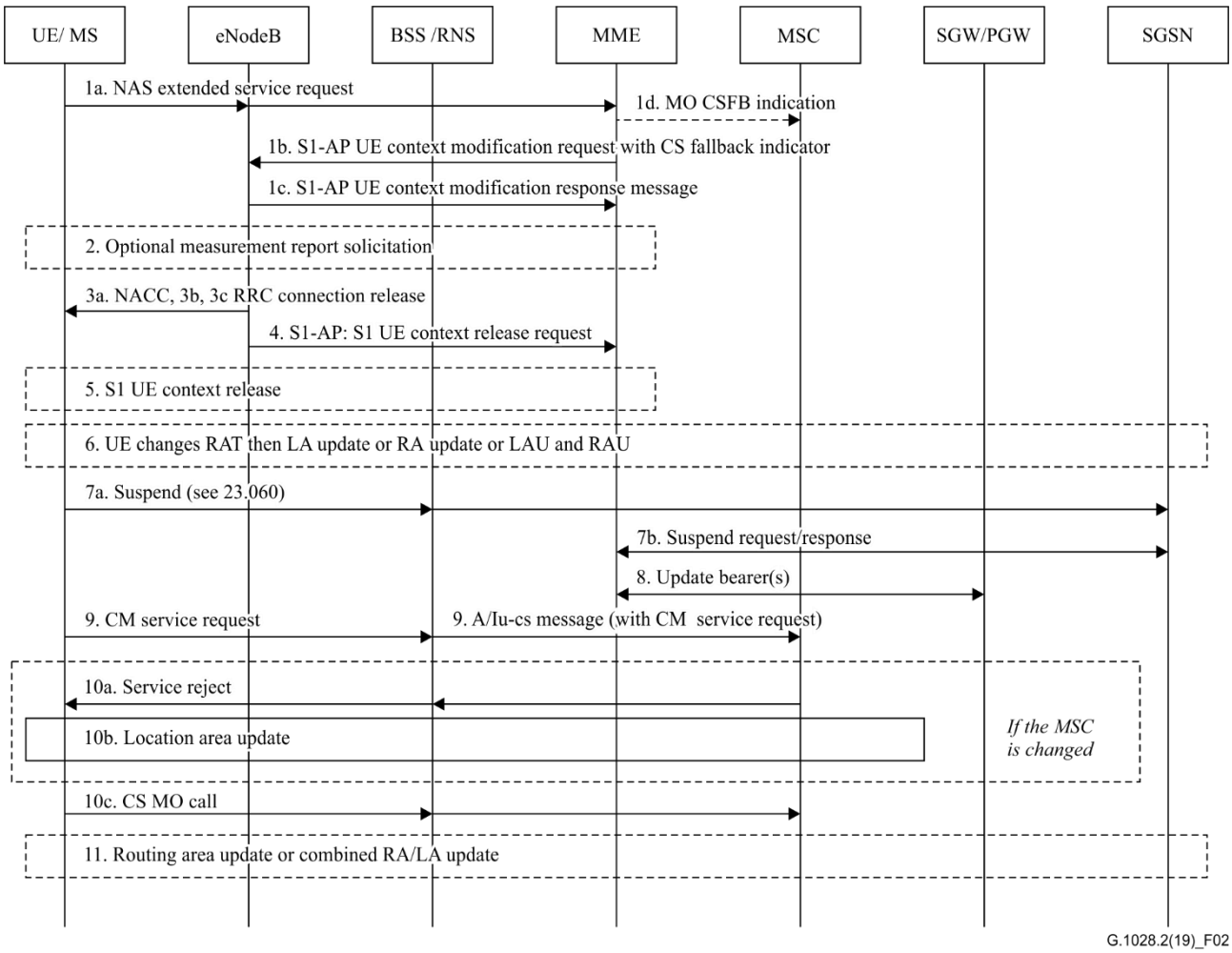

Figure 2 – Mobile originating call in active mode – No PS HO support [ETSI TS 123 272]

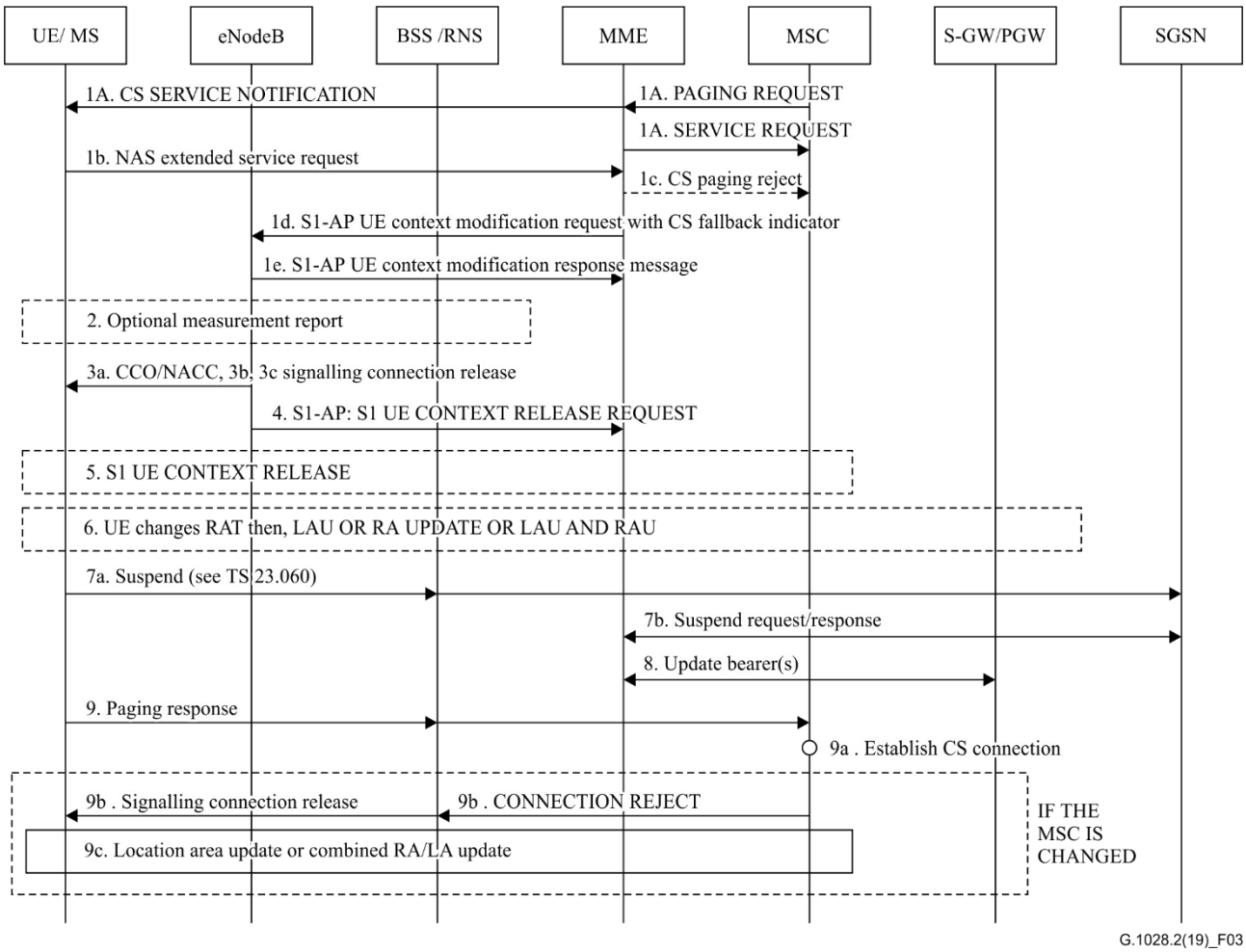

Figure 3 – Mobile terminating call in active mode - No PS HO support [ETSI TS 123 272]

At the end of a CSFB call, the UE can re-register to the LTE network.

This Recommendation focusses on the impact of the CSFB procedure on QoS and the assessment of this impact. Readers interested in a more detailed description and understanding of the procedure itself can refer to [ETSI TS 123 272] or to documents such as the ones provided in the bibliography.

7 KPIs for circuit switched fallback

End-to-end quality indicators provided in clause 9 (Table 2) of [ITU-T G.1028] apply for all calls starting under LTE coverage. This includes not only VoLTE calls, but also calls going into CSFB procedure. These metrics are:

- Registration success rate
- Service availability
- Post dialing delay
- Voice quality (MOS-LQ)
- Mouth-to-ear delay
- Call drop rate
- Speech bandwidth (NB, WB or SWB)

This clause provides further complementary indicators necessary to quantify the specific impact of this procedure on QoS.

Moreover, this clause assumes that the UE is already connected to an LTE network and has therefore passed initial connection, authentication and attach phases.

The relevant indicators from an end-to-end perspective, as perceived by an end-user located under a dual 4G and 3G/2G network coverage, are described in clauses 7.1 to 7.4, together with the potential contributor network key performance indicator(s) (KPI(s)).

For all ITU-T G.1028 clause 9 (Table 2) end-to-end quality indicators, and for the set of indicators from an end-to-end perspective as perceived by an end-user described in clauses 7.1 to 7.4, the full context of the measurements should be supplied, including the time interval when the KPI measurements were collected, when reporting results.

7.1 CSFB call setup failure ratio

Definition: Number of calls successfully started by end users on a 4G/LTE network that are unsuccessfully switched to a 2G/3G network, divided by the total number of call attempts, expressed as a percentage.

Corresponding network KPIs and triggering points: The CSFB procedure starts with the sending of the "RRC Connection Request" message with cause "mt_Access"by the calling party or of the "EMM Extended Service request (CS fall back indicator)" message by called party. It ends successfully if the "Setup" Message is received from network.

Formula:

$$\text{CSFB Call Setup Failure Ratio [\%]} = \left(\frac{\text{unsuccessful CSFB call setup attempts}}{\text{Total number of CSFB call setup attempts}}\right) \text{X100\%}$$

As defined in [ETSI TR 103 219], section 4.3.4.

7.2 CSFB call set-up time

Definition: The time it takes to perform the CSFB procedure, i.e., the total time required to start and complete the CSFB procedure from the UE of the calling party.

From the end-user's perspective, this metric is strictly equivalent to post dialing delay as defined in ITU-T G.1028. It corresponds to the sum of the CSFB Time –calling party (as defined in [ETSI TR 103 219], section 4.3.3) and of the call setup time on the CS (2G or 3G) network.

Corresponding network KPIs and triggering points: This metric corresponds to the measurement of the delay between the moment the "NAS CM Service Request" is sent with "CSFB requested" clause (or "RRC Connection Request" with cause "mo_Data") to the reception of "NAS ALERTING" message on the target network.

Formula:

$$\text{CSFB Call Setup Time (s)} = (t_{\text{calling party receives alerting tone}} - t_{\text{user press call button}})$$

7.3 CSFB return to 4G/LTE time

Definition: The average time (in seconds) it takes for a UE to return to 4G from a legacy (2G/3G) network after a CSFB call has been ended by end-user.

Corresponding network KPIs and triggering points: The return to 4G starts with the normal clearing message (NAS disconnect) and finishes when the first system information block (SIB) message has been received and decoded in LTE.

Formula:

$$Return\ to\ 4G/LTE[s] = t_{\text{first System information block in LTE received}} - t_{\text{call disconnected}}$$

As defined in [ETSI TR 103 219], section 4.3.7.

NOTE – A meaningful measurement result may be the average of this metric.

7.4 CSFB return to 4G/LTE failure ratio

Definition: The probability that a UE is able, in a given time interval, to return to 4G from a legacy (2G/3G) network after a CSFB call has been ended by end-user.

Corresponding network KPIs and triggering points: Similar trigger points to CSFB Return to 4G/LTE time, with in addition the possibility for the end trigger to be reached within a predefined time interval

Formula:

$$\text{Return to 4G LTE Failure Ratio (\%)} = \left(1 - \frac{\text{unsuccessful Return to LTE attempts}}{\text{Total Return to LTE attempts}}\right) * 100$$

As defined in [ETSI TR 103 219], section 4.3.6.

7.5 Quality targets

Similar to the process in ITU-T G.1028 (Tables 4 to 7) for most of the indicators identified for VoLTE, a budget must be assigned for the indicators identified in clause 7 to the various segments that compose end-to-end paths, with indications of target values that can be reasonably reached on each of these segments.

NOTE – Due to a lack of field feedback, this section is for further study. Table 1 will be completed once such feedback becomes available.

Table 1 – Quality budget allocation

Network segment	CSFB call setup failure ratio	CSFB call setup time	CSFB return to 4G/LTE time	CSFB return to 4G/LTE failure ratio
UE				
E-UTRAN				
UTRAN /GERAN				
EPC				
IMS/AS				
Total budget				

8 Assessment methodology for CSFB

The very nature of the CSFB procedure requires particular considerations when it comes to the measurement methods. In particular, since it involves correlation of events taking place in different radio access technologies (RATs), collection of information from different points and subsequent correlation is required in order to capture the requested information.

However, a few similarities remain with the case of VoLTE discussed in [ITU-T G.1028], which are highlighted in the clauses that follows. The use cases for reporting, monitoring and troubleshooting described in ITU-T G.1028 also apply for CSFB use cases.

NOTE – In complement to methods described below, crowdsourcing based approaches may be envisaged. Further study is, however, required in order to prove their practical and reliable application to collect technical KPIs for VoLTE and CSFB.

8.1 Passive monitoring

Simultaneous monitoring of S1-Application Protocol (present in S1 interfaces, see measurement points C1 and D1 in ITU-T G.1028), SG and A/IuCS interfaces enable the capturing of the messages pertaining to the different phases of the CSFB procedures regardless of the initial state of the UE. Subsequent correlation (using unique identifiers such as IMSI, IMEI and activities timestamp) allows the connection of the different portions of the procedure and the generation of the required KPIs. This approach guarantees statistical validity of the samples since it will capture all CSFB attempts.

8.2 Active monitoring

When using active monitoring (at either measurement points A2 or A3 as defined in ITU-T G.1028) it is important to identify the correct working conditions for the test set. Due to the very nature of this type of test, it can successfully be used to verify CSFB procedure in a restricted area (i.e., hospitals, airports, etc.) but cannot guarantee that the information collected can be representative of the situation on a larger scale. Specific biases may also be introduced by the type of device being used and its software release. As a result of these limitations it is recommended that active monitoring is used to monitor only specific locations and analysis is restricted on the trend over time of the collected data (i.e., improving/degrading) and not to use these data on a national scale to monitor networks performances.

8.3 Drive testing

Considerations similar to those discussed for active monitoring in clause 8.2 can also be made for drive testing (see measurement point A3 in ITU-T G.1028). In particular, isolating the measurement conditions in place for such a complex procedure like CSFB (involving different passages in different networks) has a negative impact on the reliability of the measurements obtained using drive testing technologies.

Similarly to what was previously discussed, parameters such as brand/model of the UE, OS software version as well as other aspects impacting radio frequency (RF) performances (e.g., utilization of internal or external antennas and their relative positioning when using multiple UEs at the same time) should be taken in account when using drive testing. Nevertheless, drive testing can provide useful insight on CSFB performance when considered on a punctual basis (i.e., using the obtained data as representative only for this specific moment in time/in space).

8.4 Trace files/other network related information

If trace file functionality is enabled, it is possible to collect the information contained in these files related to CSFB event and to correlate them (using a post-processing tool) to obtain the specified KPIs. Specifications for the trace file formats and their contents vary from vendor to vendor and therefore specific analysis based on the technology to be monitored have to be put in place.

9 Impact on QoS

This clause complements Tables A.1 and A.2 in Annex A of [ITU-T G.1028] with a list of degradations of QoS for voice services that are specific to CSFB:

Table 2 – Degradations related to call session performance and their potential causes

Degradation	Possible reasons:	Location
Unavailability of basic call	– Failure during any of the phases of CSFB procedure	Terminal/eUTRAN/UTRAN
Link failure	– Bad negotiation between two equipment of the network during CSFB procedure (bad codec management)	eUTRAN/UTRAN
PS session retention	– In case of CSFB procedure, pre-existing data session on 4G may have to be handed over to 3G with a lower bit-rate, or suspended until the UE comes back to 4G.	Terminal/eUTRAN

Table 3 – Degradations related to perceived speech quality and their potential causes

Kind of degradation	Possible reasons:	Location
Encoding/decoding issues	– Narrowband instead of wideband speech quality – No VoLTE available, CSFB procedure is applied back to NB CS telephony	Terminal/UTRAN

Bibliography

[b-Netmanias Tech-Blog]: Netmanias Tech-Blog, *Part-2: What happens when a user performs a voice call from an LTE/4G network? – VoLGA & CSFB*; accessed in August 2019.
<https://www.netmanias.com/en/post/blog/10906/lte-volte/part-2-what-happens-when-a-user-performs-a-voice-call-from-an-lte-4g-network-volga-csfb>

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