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Contents

Foreword

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Introduction

Voice-over-LTE (VoLTE) may require better LTE Reference Signal Received Power (RSRP) compared to data service, i.e. while the LTE radio signal may be good enough for pure data session, it may not be reliable enough for VoLTE services. In scenarios where the radio network is dimensioned for data services, eNB may trigger SRVCC handover to CS, e.g. when the UE falls into marginal or weak LTE coverage or when an EPS bearer with QCI-1 reliability is not sufficiently met.

In certain network dimensioning, the VoLTE coverage border may be a function of the selected codec and its selected configuration, its rate and mode adaptation, and potentially the applied application layer redundancy, as well as the required QoS of the VoLTE bearer. In these cases, legacy RAN might unnecessarily hand over fairly good VoLTE calls to 2G/3G CS via SRVCC HO, because it is unaware of the robustness of the selected codec. Radio Resource Management functions could potentially avoid unnecessary SRVCC HOs, if appropriate information is made available.

TS 26.114 (which is used as basis for the GSMA IR.92 VoLTE profile) includes several tools for increased robustness of speech calls with initial selection of Codecs and their Configuration and in-call dynamic rate and mode adaptation and maybe application layer full redundancy. EVS, especially the EVS Channel Aware mode, demonstrates higher robustness against transmission errors than AMR and AMR-WB codecs by application-layer partial redundancy.

The present document investigates possible solutions to maintain voice quality on LTE as high as possible and by that avoiding or at least delaying SRVCC as much as possible and by that minimize the negative impact on user experience for VoLTE subscribers in areas with weak LTE coverage.

The recommendations and conclusions of this document were used to develop the Coverage and Handoff Enhancements for Multimedia (CHEM) feature which extended beyond SRVCC and LTE to general handoffs. Aside from inter-domain handoffs, this added intra-domain handoffs that also includes intra-system and inter-system handoffs for any type of media. Normative and informative annexes for this are specified in 3GPP TS 26.114 [3].

1 Scope

The present document provides a study on the enhanced VoLTE performance (eVoLP). The study focuses on:

- Guidelines or requirements to ensure that MTSI clients send requests to adapt to robust modes of codec operation when necessary. This study may require investigating performance results for different conditions and adaptation procedures.
- Mechanisms to indicate at setup a terminal's ability to send adaptation triggers (e.g. to adapt to the most robust codec mode).
- Evaluate the impact of proprietary client implementations of Packet-Loss Concealment and Jitter Buffer Management (JBM) on having different Max PLR and potential mechanisms to indicate this to the network.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TR 21.952: "Codec for Enhanced Voice Services (EVS); Performance characterization".

[3] 3GPP TS 26.114: "IP Multimedia Subsystem (IMS); Multimedia telephony; Media handling and interaction".

[4] 3GPP TS 26.445: "Codec for Enhanced Voice Services (EVS); Detailed algorithmic description".

[5] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification"

[6] IETF RFC 4585 (2006): "Extended RTP Profile for Real-time Transport Control Protocol (RTCP) - Based Feedback (RTP/AVPF)", J. Ott, S. Wenger, N. Sato, C. Burmeister and J. Rey.

[7] Rep. ITU-R M.2135: "Guidelines for evaluation of radio interface technologies for IMT-Advanced", 2008.

[8] 3GPP TS 23.203: "Policy and charging control architecture".

[9] 3GPP TS 23.401: "General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access".

[10] 3GPP TR 23.759: "Study for enhanced Voice Over LTE (VoLTE) Performance".

[11] GSMA IR.92 (06/2017): "IMS Profile for Voice and SMS v11.0".

[12] IETF RFC 4867: "RTP Payload Format and File Storage Format for the Adaptive Multi-Rate (AMR) and Adaptive Multi-Rate Wideband (AMR-WB) Audio Codecs", J. Sjoberg, M. Westerlund, A. Lakaniemi, Q. Xie.

[13] IETF RFC 3550 (2003): "RTP: A Transport Protocol for Real-Time Applications", H. Schulzrinne, S. Casner, R. Frederick and V. Jacobson.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

DL	Downlink (from eNB to UE)
eVoLP	Enhanced VoLTE performance
JBM	Jitter buffer management
Max. PLR	Maximum end-to-end packet loss rate
PLR	Packet loss rate
UL	Up-link (from UE to eNB)

4 Overview

4.1 Introduction

4.2 UE-based and Network-based Architectures

4.2.1 Network-based Architecture

The network-based solution relies on the fact that the information on the negotiated codecs and configurations (or codec modes) for the session is available in the PCRF through its knowledge of the SDP that contains the negotiated session parameters. Based on such information, the PCRF can derive the relevant robustness parameter information (e.g. Maximum Packet Loss Rate) and signal this information to the eNB, using the procedures defined in TS 23.203 [8] and TS 23.401 [9]. The derivation of the robustness parameter information based on the negotiated codec modes can be performed subject to a standardized mapping rule, e.g. with an indication of packet loss rate for each codec mode and calculation of the Maximum Packet Loss Rate based on the negotiated codec modes. The network-based solution is depicted in Figure 4.1.

In this solution, the PCRF by default does not know the MTSI client adaptation behavior, and would therefore set the robustness parameter (e.g. Maximum Packet Loss Rate) based on the least robust codec mode among the negotiated codec configurations. If however the PCRF knows from the SDP that the MTSI client receiver supports adaptation to the most robust codec mode, i.e. that the UE will request the sender to change its encoder to a more robust mode when it detects packet losses, then the PCRF could set the robustness parameter based on the most robust codec mode, and thereby potentially enabling enhanced optimized SRVCC handover performance. Such indication to the PCRF is enabled via the new SDP parameter 'adapt', see clause 7.2.1 for further details.

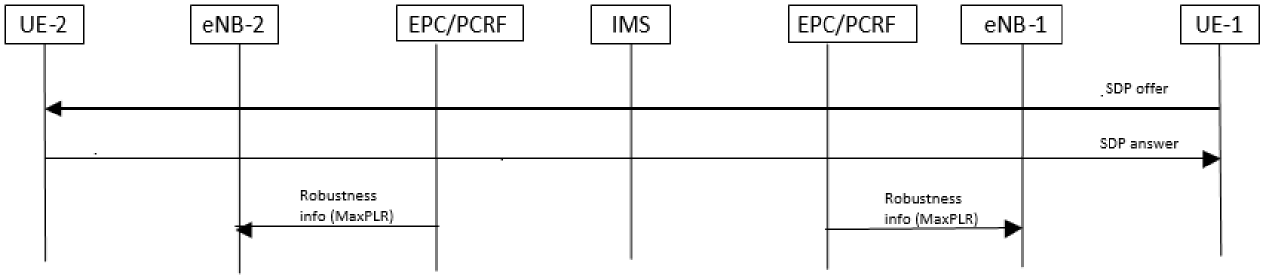


Figure 4.1: Network-based solution to signal robustness information to eNB

4.2.2 UE-based Architecture

The UE-based solution relies on the fact that the information on the negotiated codecs and configurations (or codec modes) for the session is available in the UE through its knowledge of the SDP that contains the negotiated session parameters. Based on such information, the UE can derive the relevant robustness parameter (e.g. Maximum Packet Loss Rate) and signal this to the eNB. Such signaling from the UE to the eNB would have to be defined in the RAN, e.g. via use of RRC signaling to carry the robustness parameter information in TS 36.331 [5] (the exact format of the signaling may be decided by RAN2). The derivation of the robustness parameter information based on the negotiated codec modes can be performed subject to a standardized mapping rule, e.g. with an indication of packet loss rate for each codec mode and calculation of the Maximum Packet Loss Rate based on the negotiated codec modes. The UE-based solution is depicted in Figure 4.2.

For the UE-based solution, one can observe that the UE (i.e. MTSI client) not only knows the negotiated codecs and configurations (or codec modes), but also the selected codec configuration or mode for the currently transmitted RTP stream, i.e. as determined via the outcome of the media adaptation in the UE. As such, the UE can determine the packet loss rate corresponding to the selected codec configuration and signal the relevant robustness parameter information (e.g. MaxPLR) to the eNB. Therefore, an indication at the SDP level via the 'adapt' parameter as described in clause 7.2.1 is not necessary for the UE-based signaling solution, and an enhanced SRVCC handover performance can potentially be ensured without supporting the 'adapt' feature in the SDP and enforcing a particular adaptation behavior on the MTSI client in the UE. Moreover, depending on the change in the selected codec configuration or mode, the UE can dynamically update the eNB on the corresponding robustness parameter information, e.g. updated value for MaxPLR.

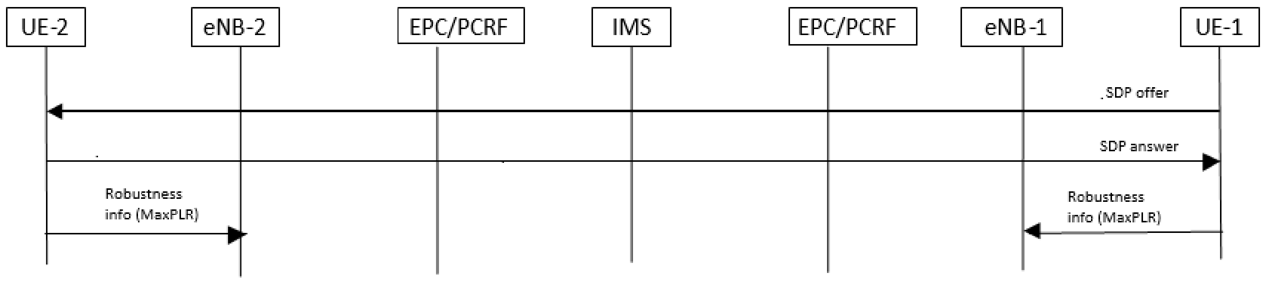


Figure 4.2: UE-based solution to signal robustness information to eNB

5 Parameters for SRVCC Handover Thresholds

5.1 Description

In this study, the parameters considered in TR 23.759 [10] are reused. In particular Max PLR in UL and DL directions is a parameter that indicates the maximum Packet Loss Rate that the specific codec mode is able to experience without degrading the voice quality.

5.2 Potential Solutions

5.2.1 Robustness Indication

5.2.1.1 Maximum Packet Loss Rate (PLR)

5.2.1.1.1 General

Based on the 3GPP EVS Selection and Characterization results that included AMR-WB, AMR-WB encoder with ITU-T G718IO decoder, and EVS codec, this clause provides an example set of Max. PLR operating points that the terminal may indicate to the PCRF.

5.2.1.1.2 Max PLR recommendation without Application Layer Redundancy

Table 5.1 provides an example Maximum PLR operating points based on the EVS Selection and Characterization experiment results.

Based on the EVS Characterization experiment results, e.g. Figure 11.10 and Figure 11.17 in TR 26.952 [2] the following can be noted:

- Compared against AMR-WB/EVS AMR-WB-IO modes, the subjective quality performance gap with EVS-SWB Channel Aware mode increases from about 0.3 DMOS to 0.75 DMOS. For example, EVS SWB CA 13.2 kbps at 9% FER is NWT than that of AMR-WB (or EVS-IO) at 23.85 kbps at 3% FER.

Based on the EVS Selection experiment results, e.g. Figure 10.2 in TR 26.952, the following can be noted.

- the performance of EVS WB at 6% FER (solid red line) is similar to that of the AMR-WB/G.718IO at 3% FER (dotted blue line). Note that AMR-WB/G.718IO incorporates enhanced decoder-side packet loss concealment techniques that are not specified in AMR-WB codec.

Based on the EVS Selection experiment results, e.g. Figure 10.12 in TR 26.952, the following can be noted.

- the performance of EVS AMR-WB IO at a given FER is similar to that of AMR-WB/G.718IO at the same FER.

Table 5.1: Example Maximum End-to-end Packet Loss Rate (PLR) per link for AMR-WB, EVS

Codec	Robustness Parameter	Maximum End-to-end Packet Loss Rate
AMR-WB	Normal	1.5%
AMR-WB/G718 IO, EVS AMR-WB IO	Medium	3%
EVS WB, SWB	High	6%
EVS WB, SWB Channel Aware	Extreme High	9%

5.2.1.1.3 Max PLR recommendation with Application Layer Redundancy

Application layer redundancy can work in conjunction with any of the aforementioned codec modes in Table 5.1, and may in general improve the Max. PLR operating points.

Unlike the EVS channel aware (partial redundancy) codec mode for which there are test results (see TR 26.952) that may be used to derive the Maximum PLR operating points, the derivation of the Max. PLR operating points with Application Layer Redundancy may depend on many factors, e.g.:

- Different redundancy levels (100% or 200% or 300%).

- Rate and intervals at which the packets are repeated and transmitted.

- Underlying changes to the codec audio bandwidth (e.g. super-wideband to wideband and drop in intrinsic quality) if the codec bitrate is reduced to allow for packet repetitions.

Conducting subjective tests to measure the performance of application layer redundancy is one way to obtain some guidance. However, repeating the same level of subjective testing rigor to study the eVoLP performance with all potential application layer redundancy modes is simply too complex. Therefore, it is more practical to limit the number of application layer redundancy modes, e.g. use only 100% redundancy modes.

In general, use of application layer redundancy (i.e. packet repetitions) may have benefits to improve error performance, but to assess what is the Max. PLR operating point for improving eVoLP performance is challenging, especially to provide analytical guidance on top of the case when application layer redundancy is not used. For example, if one is operating at EVS 24.4 kbps SWB and encountered an FER of 10%, use of application layer redundancy with 2x9.6 kbps (to stay within the same data rate) may improve the effective loss rate to about 1%. However, the drop in the intrinsic quality of the EVS codec at 9.6 kbps relative to that of at 24.4 kbps needs to be accounted for when setting the Max. PLR operating point. Similarly, if one is operating at EVS 13.2 kbps SWB, and encounters an FER of 10%, use of application layer redundancy with 2x5.9 kbps (to stay within the same data rate) may improve the effective loss rate to about 1%, with the cost that SWB coding is not supported at 5.9 kbps.

Table 5.2: Example Max. End-to-end Packet Loss Rate (PLR) with application layer redundancy for EVS codec

Codec	Robustness Parameter	Maximum End-to-end Packet Loss Rate
No application layer redundancy, EVS (@ bitrate of R kbps)	-	X %
With 100% application layer redundancy, EVS (@ bitrate of 2R kbps), Offset=2.	-	(X+2)% to (X+5) %

NOTE: The relationship to path loss when operating at twice the bit rate is not accounted in the Max. PLR value in Table 5.2.

Table 5.2 provides example Maximum PLR operating points with and without application layer redundancy applicable to EVS codec based on informal objective and subjective results in Annex A. The example Max. PLR values in Table 5.2 for EVS includes 100% application layer redundancy with offset 2, resulting in (2xbitrate). In particular, from Figure A.1 and Figure, A.2, it can be noted that similar MOS-LQO values are observed for the following, 1) EVS @2x7.2 kbps at 6% FER and EVS @13.2 kbps at 4% FER, 2) EVS 2x13.2 kbps at 8% FER and EVS 13.2 kbps at 3% FER, and 3) EVS 2x9.6 kbps at 6% FER and EVS 24.4 kbps at 3% FER. With the use of application layer redundancy, it is not straightforward to set the Max. PLR parameter as it will depend highly on the configuration and the bitrates used. To this extent, in Table 5.2, a range of possible Max. PLR improvements that can be feasible, e.g. 2-5% are suggested. That is if the Max. end-to-end packet loss rate that a terminal can handle is X% when there is no application layer redundancy (e.g. as per Table 5.1), then with the application layer redundancy the Max. PLR end-to-end packet loss rate that a terminal can similarly handle may increase to the range of (X+2)% to (X+5)%. It is not straightforward to obtain a reliable single Max. PLR value for various configurations of application layer redundancy; and it is up to the service provider to evaluate the network configuration and select a suitable Max. PLR value when using application layer redundancy for eVoLP. Another aspect to take into consideration is that even though it may be possible that the codec (or codec configurations) can handle maximum end-to-end packet loss rate in the range of e.g. 12%, the radio link may be quite unstable at those channel conditions.

The use of application layer redundancy introduces the following considerations:

1) Increasing the aggregate bit rate can:

    - further reduce coverage, which is the opposite to the objective of the eVoLP feature. This was not simulated in the study.

    - increase the packet loss rate provided by the RAN as it is supporting a higher bit rate. This was not simulated in the study.

2) Keeping the aggregate bit rate the same by reducing the codec bit rate (e.g. 13.2 -> 2 x 7.2) can reduce the voice quality as a lower rate codec is used. This was not taken into account in the study.

3) Reserving QoS resources for a data rate more than required by the highest codec mode negotiated to support application layer redundancy may result in a waste of network resources if the application layer redundancy is never used. This consideration can limit the number of codec modes with which application-layer redundancy can be used. For example, a configuration may not reserve more QoS than is required by the highest codec mode negotiated. When application layer redundancy is used in such configuration it can only be used with lower rate codec modes.

5.3 Conclusion

For eVoLP SRVCC threshold selection, it is recommended to use the example Max. PLR operating points as per clauses 5.2.1.1.1 and clauses 5.2.1.1.2.

6 Codec Mode Adaptation Procedures

6.1 Description

6.2 Potential Solutions

6.2.1 Adaptation to Packet Loss

The main clause dealing with adaptation in TS 26.114 is clause 10 and example adaptation algorithms for speech are provided in Annex C of TS 26.114. There are no mandatory adaptation mechanisms, however clause 10 provides some high-level guidelines (e.g. conservative use of adaptation). TS 26.114 currently defines two methods to signal adaptation requests for speech:

- RTP CMR in the codec payload
- RTCP-APP

Note that additional mechanisms are available (e.g. ANBR for bitrate adaptation and ECN-triggered adaptation). RTCP-APP is recommended for speech adaptation defined in clause 10.2.1 of TS 26.114 (including application-layer redundancy). However, it is also specified that AVPF will be offered when offering to use RTCP-APP signalling.

The procedures for client adaptation to packet loss can be introduced in Annex C of TS 26.114, similar to how the procedures for rate adaptation are specified. This would be specified as follows:

In 3GPP TS 26.114 [3]:

"C.1.3.6 Adaptation to Packet Loss

When the MTSI client detects packet losses higher than tolerable by the current codec mode and application layer redundancy in use (if any), then the MTSI client should use the CMR or RTCP-APP messages to request a more robust codec mode or increased application layer redundancy from the media sender."

6.3 Conclusion

It is recommended to add the procedures to client adaptation to packet loss in TS 26.114 as per clause 6.2.1.

7 Adaptation Capability Indication

7.1 Description

Void.

7.2 Potential Solutions

7.2.1 SDP Indication

7.2.1 SDP Indication

A new SDP attribute (e.g. "PLR_adapt") can be defined to indicate that the MTSI client receiver supports adaptation to the most robust codec mode, i.e. that the UE will request the sender to change its encoder to a more robust mode when it detects packet losses.

The "PLR_adapt" SDP attribute is necessary so that the UEs and network can confirm that the MTSI clients will be able to adapt to the most robust codec mode negotiated for the session. When the attribute is sent by an MTSI client in SDP (Offer or Answer) this indicates that when the MTSI client detects high packet loss in the received media stream, the MTSI client will request that the media sender use a more robust codec mode among those negotiated.

During the design of the Coverage and Handoff Enhancements for Multimedia (CHEM) feature it was determined that some network operators may want to disable the MTSI client's ability to perform robustness adaptation (e.g., network wants to guarantee that UEs from different vendors do not change codec modes at different PLR values before performing SRVCC). To support this, the "PLR_adapt" SDP attribute was modified from being a capability indication to become an attribute for negotiating use of the CHEM feature, i.e., the MTSI client shall only perform robustness adaptation when it receives the "PLR_adapt" attribute from the other MTSI client. To disable the feature the network could remove the SDP attribute during SDP negotiation.

For the network-based solution, the PCRF can use the presence of the "PLR_adapt" attribute in SDP to determine what Max PLR to indicate to its eNB as follows:

a) If the PCRF detects the "PLR_adapt" attribute in both the SDP offer and answer, but does not detect the "ALR" parameter, then the PCRF can indicate,

    a) the Max PLR for the **most robust** codec mode that does not use application layer redundancy negotiated in the downlink direction to the eNB for its downlink. Otherwise, if the "PLR_adapt" attribute is not detected, the PCRF indicates the Max PLR for the **least robust** codec mode negotiated in the downlink direction to the eNB for its downlink

    b) the Max PLR for the **most robust** codec mode that does not use application layer redundancy negotiated in the uplink direction to the eNB for its uplink. Otherwise, if the "PLR_adapt" attribute is not detected, the PCRF indicates the Max PLR for the **least robust** codec mode negotiated in the uplink direction to the eNB for its uplink

b) If the PCRF detects the "PLR_adapt" attribute in both the SDP offer and answer, and also detects the "ALR" parameter, then the PCRF can indicate,

    a) the Max PLR for the **most robust** codec mode (including those that rely on application layer redundancy) negotiated in the downlink direction to the eNB for its downlink. Otherwise, if the "PLR_adapt" attribute is not detected, the PCRF indicates the Max PLR for the **least robust** codec mode negotiated in the downlink direction to the eNB for its downlink

    b) the Max PLR for the **most robust** codec mode (including those that rely on application layer redundancy) negotiated in the uplink direction to the eNB for its uplink. Otherwise, if the "PLR_adapt" attribute is not detected, the PCRF indicates the Max PLR for the **least robust** codec mode negotiated in the uplink direction to the eNB for its uplink

Figure 7.1: void

Figure 7.2: void

The PLR_adapt SDP attribute applies to the entire media line, i.e., either all of the codecs support robustness adaptation or none do.

7.2.2 Application Layer Redundancy Adaptation Request

7.2.2.1 General

Application layer redundancy is a codec-agnostic feature and not a codec mode as such. For example, the application layer redundancy may be used in conjunction with the current codecs AMR or AMR-WB or EVS AMR-WB IO or EVS with or without Channel aware. The use of application layer redundancy requires use of the RTCP-APP redundancy request message as specified in clause 10.2.1.3, TS 26.114 [3]. However, other signalling options than RTCP-APP are studied in another clause.

Further, as per GSMA RiLTE specification IR 92 v11.0, it was specified that "RTCP-APP must not be used for Codec Mode Requests (CMR) by the UE and the entities in the IMS core network that terminate the user plane", and AVPF will not be used. The use of RTCP-APP is therefore restricted for use of requesting application layer redundancy.

GSMA IR.92 specifies that "the RTP AVP profile must be used by the client and IMS network. Besides, entities must be able to ignore SDPCapNeg attributes and indicate the use of the RTP AVP profile when clients support both AVP and AVPF". With this minimum profile of MTSI, it is therefore not possible to use RTCP-APP with the AVPF profile which could affect performance of media robustness adaptation due to signalling latency. The primary uses of RTCP are voice quality monitoring and keep-alive functionality.

7.2.2.2 Signal method 1: RTCP-APP

RTCP-APP signalling is defined in TS 26.114 [3], clause 10. This method does not seem applicable with the current minimum profile defined in GSMA IR.92 [11].

7.2.2.3 Signal method 2: RTP CMR using the Reserved CMR codepoints

RTP CMR for AMR and AMR-WB is specified in IETF RFC 4867 [12]. The 4-bit CMR code space is not fully used and allows to signal bit rate adaption requests for the 8 and 9 modes of AMR and AMR-WB, together with the NO_REQ code. Some CMR code points are left for future use.

RTP CMR for EVS is specified in Annex A of TS 26.445. In Compact mode, there is only a 3-bit CMR for EVS AMR-WB IO to signal 7 out 9 modes and a 'none' code equivalent to 'NO_REQ'. A CMR byte is defined for Header-full mode, with code points for operation mode / bit rate / coded bandwidth adaptations (EVS-NB, -WB, -SWB, and -FB and AMR-WB IO), together with specific requests for EVS CAM at different offsets and FEC indicators. There is also a specific code point for NO_REQ in the CMR byte. The code space in the CMR byte is sparse with many entries indicated as 'Not used' and some entries indicated as 'reserved'.

The existing code points for RTP CMR in AMR and AMR-WB can only be used for bit rate adaptation while RTP CMR for EVS is able to signal adaptation requests in terms of operation mode / bit rate / coded bandwidth / CAM mode adaptation. To be able to signal other types of requests, such as application-layer redundancy or frame aggregation, one has to rely on RTCP-APP, however this is not allowed in IR.92.

Assuming there is a specific new SDP attribute indicating 'eVoLP capability' in the terminal for interoperability with legacy terminals (e.g. a media level attribute below the 'm=audio' line in SDP), one may reuse 'reserved' CMR codepoints for AMR, AMR-WB and EVS.

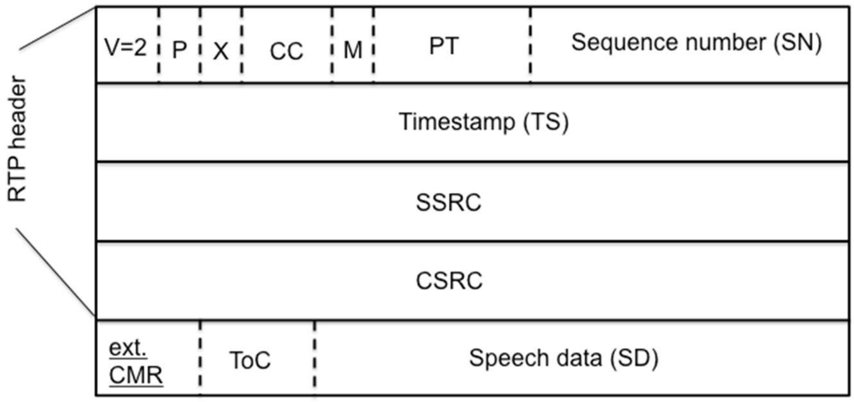


Figure 7.3: Packet structure with extended CMR (ext. CMR) by reusing reserved code points

The use of CMR to request for application layer redundancy is not possible in case of AMR-WB and EVS AMR-WB IO as there are no available points as per Table A.3 in TS 26.445 [4]. In case of EVS primary modes, repurposing the 15 Reserved Fields is highly risky given that:

- It is not clear if all the current implementations strictly ignore the Reserved Fields or reset them.
- Also, as per clause A.2.2.1.1 in TS 26.445, when a CMR is received requesting a bit rate and/or audio bandwidth that does not comply with the negotiated media parameters, it will be ignored. Any change to the TS 26.445 specification now would introduce backwards compatibility issues with legacy devices. One may have to rely on additional eVoLP related SDP attributes and/or parameters (e.g. eVoLP 'PLR_adapt' attribute and optional 'ALR' attribute) to limit the backward interop issues.

Some indicative example of code point reuse for AMR, AMR-WB and EVS are provided in Tables 7.1, 7.2, 7.3.

Table 7.1: Reusing 'reserved' code points for AMR.

CMR code	Application layer redundancy AMR request
9	RED 2x4.75
10	RED 2x5.15
11	RED 2x5.9
12	Not used
13	Not used
14	Not used

Table 7.2: Reusing 'reserved' code points for AMR-WB

CMR code	Application layer redundancy AMR-WB request
9	RED 2x6.6
10	RED 2x8.85
11	RED 2x12.65
12	Not used
13	Not used
14	Not used

Table 7.3: Example 1: Reusing 'reserved' code points for EVS.

CMR code	Application layer redundancy EVS request
111 0000	RED 2x7.2-NB
111 0001	RED 2x8-NB
111 0010	RED 2x9.6-NB
111 0011	RED 2x13.2-NB
111 0100	RED 2x7.2-WB
111 0101	RED 2x8-WB
111 0110	RED 2x9.6-WB
111 0111	RED 2x13.2-WB
111 1000	RED 2x13.2 CAM WB
111 1001	RED 2x13.2 CAM SWB
111 1010	RED 2x9.6-SWB
111 1011	RED 2x13.2-SWB
111 1100	RED 2x6.6-IO
111 1101	RED 2x8.85-IO
111 1110	RED 2x12.65-IO

7.2.2.4 Signal method 3: Padding

Assuming there is a specific new SDP attribute indicating 'eVoLP capability' in the terminal for interoperability with legacy terminals (e.g. a media level attribute below the 'm=audio' line in SDP), padding can be inserted at the end of the payload. The padding bit (P) in the RTP header may be set to 1, however this bit may also be kept to 0 to avoid impact on header compression.

Padding should be inserted following RFC 3550, where the last octet indicates the number of inserted bytes. The signalled request may be format as in RTCP-APP or as in extended CMR. In the latter case, care should be taken to avoid conflicts with the possible CMR in the payload header.

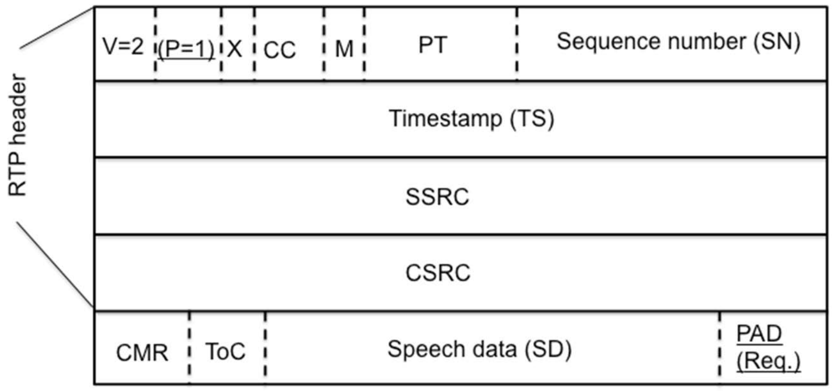


Figure 7.4: Packet structure with extended request with padding bytes

This solution is not feasible, because RTP-level padding is mandated to be set to 0 [13].

7.2.2.5 Signal method 4: RTP header extension

Assuming there is a specific new SDP attribute indicating 'eVoLP capability' in the terminal for interoperability with legacy terminals (e.g. a media level attribute below the 'm=audio' line in SDP), this capability attribute can be formatted according to RFC 8285 with the "rtp-hdrext" parameter. The extension bit (X) in the RTP header will be set to 1.

The signalled request may be format as in RTCP-APP or as in extended CMR. In the latter case, care should be taken to avoid conflicts with the possible CMR in the payload header.

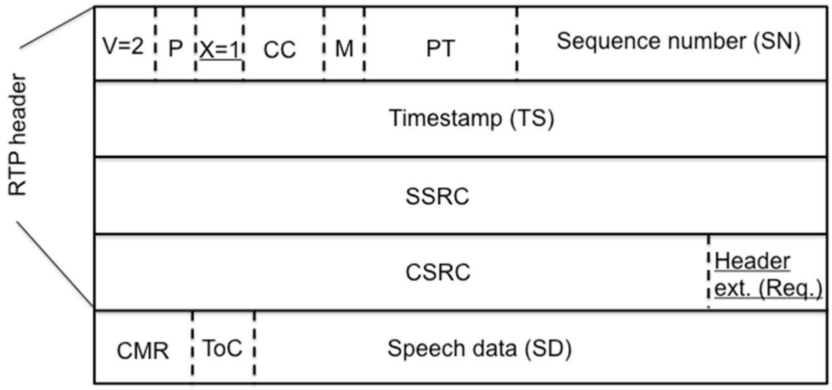


Figure 7.5: Packet structure with header extension

7.2.2.6 Conclusions on Application Layer Redundancy

With the GSMA IR.92 restrictions against using the AVPF RTP profile for speech, the solution chosen for supporting the request of application layer redundancy for speech robustness was use of the reserved RTP CMR codepoints as described in clause 7.2.2.3.

As there were no identified commercial deployments of application layer redundancy it was determined that its support not be mandated for the Coverage and Handoff Enhancements for Multimedia (CHEM) feature specified in 3GPP TS 26.114 [3]. Use of application layer redundancy has to be explicitly negotiated using an optional SDP 'ALR' parameter of the PLR_adapt SDP attribute. The use of the RTP CMR codepoints is restricted to only sessions where both MTSI clients indicate support via the 'ALR' SDP attribute, thus avoiding backwards compatibility issues with legacy terminals and enabling use of the reserved code points for future features that do not rely or co-exist with application layer redundancy.

7.2.3 Considerations on the impact of packet loss on adaptation requests

When RTP CMR is used, the CMR field is carried in RTP packets, which are typically over UDP (in unacknowledged RLC mode in LTE), so in case of packet loss the CMR field might be lost. Some possible guidelines are provided below to ensure proper behavior in impaired conditions, assuming the existing RTP CMR method is used to application layer redundancy adaptation requests:

- For AMR and AMR-WB, the CMR field is always present. Assuming an updated adaptation request has been sent in a given CMR (different from 'NO_REQ'), the code point corresponding to the targeted operation should be used and repeated until the next update of the request, instead of the 'CMR15' code point. Alternatively, one may repeat a request several times until the request is executed or up to a given timeout.
- For EVS, assuming the default packetization mode is used, sending CMR may require temporarily switching from compact to header-full (at the expense of payload size). If the terminal, which has sent an adaptation request by CMR, has not received any RTP packets matching the request after a given timeout (e.g. 500 ms), it may resend a new CMR (potentially with an updated value). There may be other approaches, for instance, the terminal may just repeat the latest updated adaptation request, however this may require using header-full mode most of the time, especially if the adaptation frequency is high or if the target is to maximize the robustness of CMR transport. Here, it is important to recall that there is some potential padding penalty used for size collision avoidance of header-full mode, which may have an impact on efficiency.

7.3 Conclusion

It is recommended to define a new SDP parameter (e.g. "PLR_adapt") to indicate that the MTSI client receiver supports adaptation to the most robust codec mode. For the network-based eVoLP solution, the PCRF can use the presence of this parameter in SDP to determine the Max. PLR to indicate to its eNB as per clause 7.2.1.

8 Impact of JBM and PLC on Handover Thresholds

8.1 Description

In addition to the negotiated codecs and codec modes, the end-to-end quality and robustness of the VoLTE connection also depends on the UE capabilities including, for example, jitter buffer management (JBM) and packet loss concealment (PLC). In the meantime, the MaxPLR parameter derived by the PCRF (i.e. in the network-based architecture in clause 4.2.1) or UE (i.e. in the UE-based architecture in clause 4.2.2) and signaled to the eNB does not capture the impact of such UE capabilities. As such, further refinements on the MaxPLR could be considered on a per UE basis depending on the capabilities of the UE.

One of the challenges in setting the handover thresholds is to ensure that the end-to-end error rate across the transport path from the media sender to a media receiver does not exceed the maximum packet loss that the codec, the PLC implementation, and the JBM implementation in the receiving UE can handle. In Figure 8.1, assuming that the backhaul introduces negligible error requires that in the transmission direction from UE B to UE A, that:

eNB_A_DL_PLR + eNB_B_UL_PLR <= max PLR codec and (PLC + JBM in UE A)

Similarly, in the other direction of transmitting media from UE A to UE B the following requirement holds:

eNB_A_UL_PLR + eNB_B_DL_PLR <= max PLR codec and (PLC + JBM in UE B)

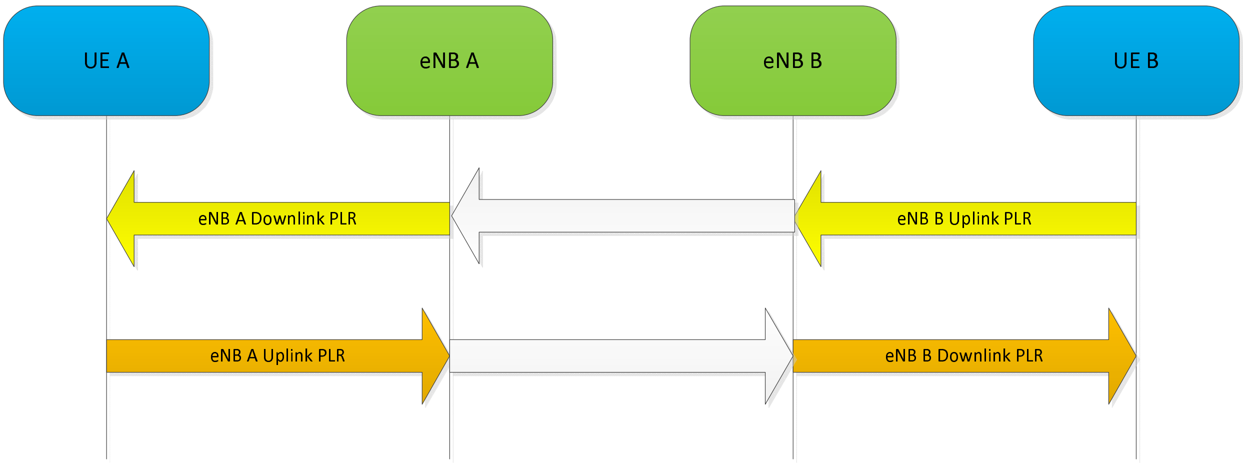


Figure 8.1: UL and DL packet loss rate depiction

The problem is how to provide the eNB information about the codec, PLC, and JBM in use so that it can set appropriate handover thresholds for the uplink and downlink.

8.2 Potential Solutions

8.2.1 General

Since the PLC and JBM implementation and performance are known only to the terminal receiving media, this information has to be signaled by the terminal to the network. In this context, the UE may consider its JBM and/or PLC capabilities to derive a recommended *maximum end-to-end packet loss rate* (max_e2e_PLR) that the terminal can tolerate for a given codec/mode when using its JBM and PLC implementation, and signal this parameter, or some indication derived from it, to the network. The robustness parameter values used in the eNB may then use, or be refined based on, this recommendation. A UE with advanced JBM and PLC capabilities may determine a max_e2e_PLR value that is higher than the MaxPLR corresponding to the most robust codec configuration. This means that the PLC and JBM capabilities of the UE may be delivering further robustness on top of that delivered by the most robust codec configuration. If the eNB gets such an indication of additional robustness from the UE, it may further delay the SRVCC handover decision even when the MaxPLR value (based on the most robust codec configuration) is exceeded, leading to more optimized SRVCC handovers.

Furthermore, since there are typically two radio links in the end-to-end path from the sending terminal to the receiving terminal, the information has to ultimately be shared with the two eNBs in the transport path to determine how to set their SRVCC handover thresholds to achieve the appropriate packet_loss_rate targets.

During SDP codec negotiation, the terminals may also exchange information about their JBM and packet loss concealment capabilities. As such, SDP may carry max_e2e_PLR information.

The value of this parameter can be set in the UE based on the UE vendor's characterization of the terminal's performance and it is exchanged with the other terminal via a new SDP parameter. For example, UE A would send the max PLR that it can receive (max_e2e_PLR_A) for a particular codec mode to UE B in the SDP offer, while UE B would send max PLR it can receiver (max_e2e_PLR_B) for a particular codec mode to UE A in the SDP answer.

8.2.2 UE-requested UL and DL PLR

8.2.2.1 General

In the following set of solutions, following the exchange of the required max_e2e_PLR in each transmission direction, the terminals determine what maximum PLR to request of each local eNB for the uplink and downlink (Figure 8.2). These requests for target PLRs on the UL and DL are sent directly from the UE to eNB using new RAN2 messages.

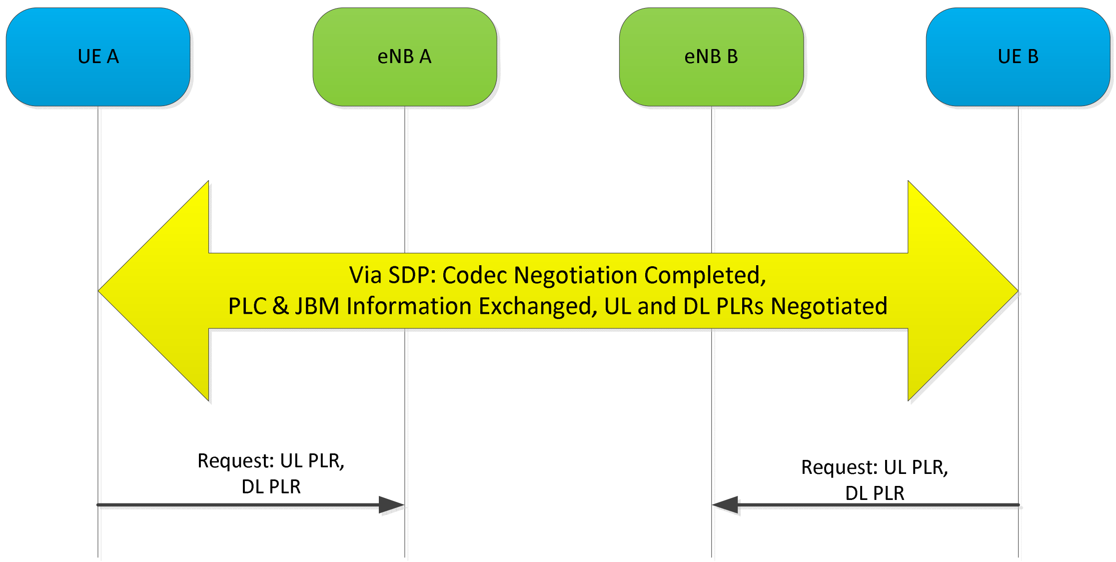


Figure 8.2: UE-requested UL PLR and DL PLR

How the UEs can determine the UL PLR and DL PLR to request of each eNB is described in the following clauses. One distinction to observe among the potential solutions is whether (i) the UL PLR and DL PLR are set statically at the session level and kept the same regardless of the local RAN conditions as in clauses 8.2.2.2 and 8.2.2.3, or (ii) the UL PLR and DL PLR are dynamically allocated according to the local RAN conditions on both ends of the link, as in clause 8.2.2.4.

8.2.2.2 Simple Ratio

In this approach the terminals are specified, pre-configured, or dynamically configured (e.g. via OMA-DM) to divide the max_e2e_PLR across the uplink and downlink according to an agreed ratio.

For example if the UL PLR: DL PLR ratio = R then:

- UE A asks its eNB to support on its uplink, UL_PLR_A = (max_e2e_PLR_B) [R /(R+1)]
- UE A asks its eNB to support on its downlink, DL_PLR_A = (max_e2e_PLR_A) [1 /(R+1)]
- UE B asks its eNB to support on its uplink, UL_PLR_B = (max_e2e_PLR_A) [R /(R+1)]

- UE B asks its eNB to support on its downlink, DL_PLR_B = (max_e2e_PLR_B) [1 /(R+1)]

8.2.2.3 SDP-Negotiated

During the SDP negotiation terminals explicitly negotiate how to distribute the max_e2e_PLR, e.g. allow more errors to occur on the uplink since LTE networks are uplink-coverage limited. This is performed as follows:

For each device, the desired UL PLR and DL PLR for its local links is pre-configured or dynamically configured via OMA-DM.

- UE A (the offerer) in its SDP offer indicates max_e2e_PLR (i.e. direction from UE B to UE A) and both its uplink (UE A to UE B) & downlink (UE B to UE A) PLRs denoted by max_e2e_PLR_Off, UL_PLR_Off, DL_PLR_Off, respectively.
- UE B (the answerer) can then either accept the requested uplink/downlink PLR or modify them. For example, if the requested uplink (UE A to UE B) PLR is more than UE B can handle, it may reduce it to fit within its max_e2e_PLR_Ans (UE A to UE B) limit.
- When UE B receives the SDP offer, it has all the information (i.e. UE A's PLR configuration and its own local configuration - UE B's max_e2e_PLR_Ans, its uplink (UE B to UE A) and its downlink (UE A to UE B)) to either accept the offer or modify what was offered. If UE B modifies what was offered by UE A and includes this in the SDP answer, UE A can either accept the payload type or reject it.
- UE B responds with its triad set. Note that if one always assumes that uplink + downlink add up to total max_e2e_PLR, then only UE B's max_e2e_PLR_Ans is needed. But to support scenarios where the network may not want to exhaust the entire PLR budget, UE B should respond with its own triad set as well.

To support the above procedures the following SDP attributes would be defined:

- Triad for the offerer: max_e2e_PLR_Off, UL_PLR_Off, DL_PLR_Off.
- Triad for the answerer: max_e2e_PLR_Ans, UL_PLR_Ans, DL_PLR_Ans.
- Where all PLRs are expressed in %.
- The following conditions should be met to provide acceptable performance:
    - UL_PLR_Off + DL_PLR_Ans will be <= max_e2e_PLR_Ans
    - UL_PLR_Ans + DL_PLR_Off will be <= max_e2e_PLR_Off

The following scenarios illustrate how these SDP parameters could be used.

Example 1

- Answerer UE configuration agrees with SDP offer therefore answerer does not modify the SDP attributes inserted by the offerer.
- Entire e2e PLR budget is utilized.

Table 8.1: SDP Offer-Answer when answerer agrees with offerer and entire e2e PLR budget utilized

SDP Offer	Value (%)	SDP Answer	Value (%)
max_e2e_PLR_Off	5	max_e2e_PLR_Off	5
UL_PLR_Off	7	UL_PLR_Off	7
DL_PLR_Off	1	DL_PLR_Off	1
		max_e2e_PLR_Ans	9
		UL_PLR_Ans	4
		DL_PLR_Ans	2

Example 2

- Answerer UE configuration agrees with SDP offer therefore answerer does not modify the SDP attributes inserted by the offerer.

- Entire e2e PLR budget is not utilized.

Table 8.2: SDP Offer-Answer when answerer agrees with offerer and entire e2e PLR budget is not utilized

SDP Offer	Value (%)	SDP Answer	Value (%)
max_e2e_PLR_Off	10	max_e2e_PLR_Off	10
UL_PLR_Off	5	UL_PLR_Off	5
DL_PLR_Off	1	DL_PLR_Off	1
		max_e2e_PLR_Ans	9
		UL_PLR_Ans	4
		DL_PLR_Ans	2

Example 3

- Answerer's PLR configuration conflicts with offerer's PLR configuration:
    - Answerer UE's PLR configuration: max_e2e_PLR_Ans=7, UL_PLR_Ans=4, DL_PLR_Ans=2.
    - Since this conflicts with offer, the answerer UE modifies the PLR values from the offer.
- Entire e2e PLR budget for answerer is utilized. Offerer's maximum e2e PLR budget is not fully utilized.

Table 8.3: SDP Offer-Answer when answerer disagrees with offerer and entire e2e PLR budget is utilized

SDP Offer	Value (%)	SDP Answer	Value (%)
max_e2e_PLR_Off	10	max_e2e_PLR_Off	10
UL_PLR_Off	7	UL_PLR_Off	5
DL_PLR_Off	1	DL_PLR_Off	1
		max_e2e_PLR_Ans	7
		UL_PLR_Ans	4
		DL_PLR_Ans	2

Answerer modifies UL_PLR_Off from 7 to 5 to fit within its maximum max_e2e_PLR_Ans. Upon receiving the above SDP answer, the offerer could either accept or reject the payload type associated with the answer.

8.2.2.4 Dynamic Allocation of UL PLR and DL PLR

The potential solutions documented in clauses 8.2.2.2 and 8.2.2.3 rely on fixed allocation of UL PLR and DL PLR across the eNBs. However, this may not always provide the most optimal results in adjusting the SRVCC handover thresholds. e.g. when one of the eNBs enjoys very good radio conditions it is unable to dynamically raise the packet loss rates that can be tolerated at the far-end eNB which would allow the far-end eNB to delay the SRVCC handover for the negotiated codec configurations. A more dynamic allocation policy on UL PLR and DL PLR that considers the local RAN conditions on both ends of the link may therefore allow realizing further optimizations on the SRVCC handover thresholds.

Considering Figure 8.1, UE_A can determine the maximum PLR it can tolerate based on its PLC and JBM implementation, i.e. max_e2e_PLR_A, and then decide how this should be distributed between eNB_A_DL_PLR and eNB_B_UL_PLR. In particular, UE A can decide on the value of eNB_A_DL_PLR based on the evaluation of the local downlink radio conditions between UE A and eNB A, and then determine eNB_B_UL_PLR by subtracting eNB_A_DL_PLR from the maximum end-to-end PLR at UE A (max_e2e_PLR). While UE A can signal eNB_A_DL_PLR to its eNB A locally over the RAN interface (e.g. via RRC signaling), it cannot signal eNB_B_UL_PLR to eNB B. UE-B may signal eNB_B_UL_PLR to eNB B, but it does not know eNB_B_UL_PLR value unless told by UE-A. To achieve the latter, UE A can use RTCP feedback or RTP header extension signaling to convey a recommended eNB_B_UL_PLR to UE B. UE B can then signal this information to eNB B locally over its RAN interface. Based on the evaluation of the local uplink radio conditions between UE B and eNB B, UE B may further update eNB_B_UL_PLR value and send this information to UE A via the use of RTCP feedback or RTP header extension messages. As such, both the MTSI receiver and MTSI sender have means to exchange UL PLR information, in order to dynamically optimize the allocation of DL PLR and UL PLR and this leads to the most optimal selection of the SRVCC handover thresholds on both ends of the link.

The potential advantage of this approach is the ability to dynamically allocate eNB_A_DL_PLR and eNB_B_UL_PLR depending on the local RAN conditions. For instance, if UE A observes that it enjoys good radio conditions to eNB A that would allow communication using the most robust codec mode with nearly negligible PLR, it may set eNB_B_UL_PLR to a value close to max_e2e_PLR_A, and essentially allocate the entire max_e2e_PLR_A for use over the eNB B's uplink toward realizing the best possible SRVCC handover threshold for eNB B in the uplink. Later on, if the local RAN conditions for UE A change, UE A may send another RTCP feedback or RTP header extension message to UE B to adjust the allocation of max_e2e_PLR_A across eNB_A_DL_PLR and eNB_B_UL_PLR.

Another possible dynamic PLR allocation approach may be when UE A determines the maximum PLR it can tolerate based on its PLC and JBM implementation and then UE B learns this maximum PLR value during the SDP negotiations. As such, UE_B (as the media sender) may then decide how max_e2e_PLR_A should be distributed between eNB_A_DL_PLR and eNB_B_UL_PLR. In particular, UE B can decide on the value of eNB_B_UL_PLR based on the evaluation of the local uplink radio conditions between UE B and eNB B, and then determine eNB_A_DL_PLR by subtracting eNB_B_UL_PLR from the maximum end-to-end PLR (MaxPLR at UE A, i.e. max_e2e_PLR_A). Again, RTCP feedback or RTP header extension methods may be used in order to convey the information on eNB_A_DL_PLR from UE B to UE A. UE A can then signal this information to eNB A locally over its RAN interface.

It should be noted that the use of the dynamic PLR allocation approach described in this clause is not limited to situations where the UEs determine the maximum PLR they can tolerate based on their PLC and JBM implementations. It is also possible that the maximum end-to-end PLRs may be decided by the network (i.e. in the PCRF) as per the network-based architecture described in clause 4.2.1 and signalled to the UEs, e.g. via max_e2e_PLR signalling using the SDP. Following this, the UEs may determine and exchange DL PLR and UL PLR recommendations based on the monitoring of their local RAN conditions, leading to a dynamic allocation of DL PLR and UL PLR.

To enable the dynamic allocation of UL PLR and DL PLR as described above, the following RTCP feedback message and RTP header extension signaling frameworks can be considered:

1) A new RTCP feedback (FB) message type to carry uplink packet loss ratio (UL PLR) information during the RTP streaming of media (signaled from the MTSI receiver to the MTSI sender).

2) A new SDP parameter on the RTCP-based ability to signal UL PLR information during the IMS/SIP based capability negotiations.

3) A new RTP header extension type to signal for UL PLR information during the RTP streaming of media (signalled from the MTSI sender to the MTSI receiver).

4) A new SDP parameter on the RTP-based ability to signal UL PLR information during the IMS/SIP based capability negotiations.

RTCP feedback messages signalled from the MTSI receiver to the MTSI sender may also carry UL PLR information for the reverse link. In this case, the use of RTP header extension messages may not be necessary.

RTP header extension messages signalled from the MTSI sender to the MTSI receiver may also carry UL PLR information for the reverse link. In this case, the use of RTCP feedback messages may not be necessary.

Instead of the UL PLR information, it is also possible that the ratio between UL PLR and DL PLR may be carried in the above messages.

The signalling of UL PLR information may use RTCP feedback messages as specified in IETF RFC 4585 [6]. As such, the RTCP feedback message is sent from the MTSI receiver to the MTSI sender to convey to the sender about the UL PLR information. The recipient of the RTCP feedback message may then convey this information to its eNB over the RAN interface, e.g. by using RRC signalling.

The RTCP feedback message may be identified by PT (payload type) = PSFB (206) which refers to payload-specific feedback message. FMT (feedback message type) may be set to the value 'Y' for UL PLR information. The RTCP feedback method may involve signalling of UL PLR information in both of the immediate feedback and early RTCP modes.

The FCI (feedback control information) format can be as follows. The FCI may contain exactly one instance of the UL PLR information, composed of the following parameters:

- UL PLR value ULPLR (16 bits)

It should be noted that this FCI format is for illustration purposes, and other formats can also be defined to convey UL PLR information.

The FCI for the proposed RTCP feedback message can follow the following format:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            ULPLR              |         zero padding          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The high byte may be followed by the low byte, where the low byte holds the least significant bits.

It is also possible that, rather than signalling UL PLR values, the ratio between UL PLR and DL PLR values may be signalled in the RTCP feedback message, e.g. in the following format:

- Ratio of UL PLR and DL PLR values UL_DL_PLR_Ratio – specified in (16 bits)

The FCI for the proposed RTCP feedback message can follow the following format:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            UL_DL_PLR_Ratio    |         zero padding          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

As yet another signalling option, it is also possible that the RTCP feedback messages may solely be used to convey the DL and UL PLR allocations for both sent and received RTP streams, e.g. with the following format:

- Ratio of UL PLR and DL PLR values UL_DL_PLR_Ratio1 for the sent RTP stream, e.g. from UE A to UE B– specified in (16 bits).

- Ratio of UL PLR and DL PLR values UL_DL_PLR_Ratio2 for the received RTP stream, e.g. from UE B to UE A – specified in (16 bits).

The FCI for this RTCP feedback message can follow the following format:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            UL_DL_PLR_Ratio1   |      UL_DL_PLR_Ratio2         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In this setting where RTCP feedback messages contain DL and UL PLR allocations for both forward and reverse links, there would not be a need to use the RTP header extension messages, in order to signal UL PLR information from the MTSI sender to the MTSI receiver. This signalling option however relies on the presence of a bi-directional link, i.e. it would not work in case of sendonly or recvonly streams.

A 3GPP MTSI client (based on TS 26.114 [3]) supporting this RTCP feedback message can offer such capability in the SDP for all media streams containing video / audio. The offer can be made by including the a=rtcp-fb attribute in conjunction with the following parameter: 3gpp-ul-plr. A wildcard payload type ("*") may be used to indicate that the RTCP feedback attribute applies to all payload types. Here is an example usage of this attribute:

```
a=rtcp-fb:* 3gpp-ul-plr
```

The ABNF for rtcp-fb-val corresponding to the feedback type "3gpp-ul-plr"can be given as follows:

rtcp-fb-val =/ "3gpp-ul-plr"

As indicated above, the UL PLR information may also be signaled by the MTSI sender to the MTSI receiver as part of the transmitted RTP stream using RTP header extensions. An example format is as follows, where UL PLR value `ULPLR` is specified in 16 bits:

```
0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   ID  | len=7 |          ULPLR                |  zero_padding |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

It is also possible that, rather than signalling UL PLR values, the ratio between UL PLR and DL PLR values may be signalled in the RTP header extension message, e.g. in the following format:

- Ratio of UL PLR and DL PLR values UL_DL_PLR_Ratio – specified in (16 bits)

An example format is as follows, where UL DL_PLR_Ratio value `UL_DL_PLR_Ratio` is specified in 16 bits:

```
0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   ID  | len=7 |       UL_DL_PLR_Ratio         |  zero_padding |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A 3GPP MTSI client (based on TS 26.114 [3]) supporting this RTP header extension message can offer such capability in the SDP for all media streams containing video / audio. This capability can be offered by including the a=extmap attribute indicating a dedicated URN under the relevant media line scope. The URN corresponding to the capability to signal UL PLR information is: urn:3gpp:ul-plr. Here is an example usage of this URN in the SDP:

```
a=extmap:7 urn:3gpp:ul:plr
```

The number 7 in the example may be replaced with any number in the range 1-14.

As yet another signalling option, it is also possible that the RTP header extension method may solely be used to convey the DL and UL PLR allocations for both sent and received RTP streams, e.g. with the following format:

- Ratio of UL PLR and DL PLR values UL_DL_PLR_Ratio1 for the sent RTP stream, e.g. from UE A to UE B– specified in (12 bits).
- Ratio of UL PLR and DL PLR values UL_DL_PLR_Ratio2 for the received RTP stream, e.g. from UE B to UE A – specified in (12 bits).

```
0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   ID  | len=7 |     UL_DL_PLR_Ratio1  |  UL_DL_PLR_Ratio2     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In this setting where RTP header extension messages contain DL and UL PLR allocations for both forward and reverse links, there would not be a need to use the RTCP feedback messages, in order to signal UL PLR information from the MTSI receiver to the MTSI sender. This signalling option however relies on the presence of a bi-directional link, i.e. it would not work in case of sendonly or recvonly streams.

Figure 8.3 below with signaling flows provides an example usage of the above dynamic DL PLR and UL PLR allocation framework based on the use of RTCP feedback signaling.

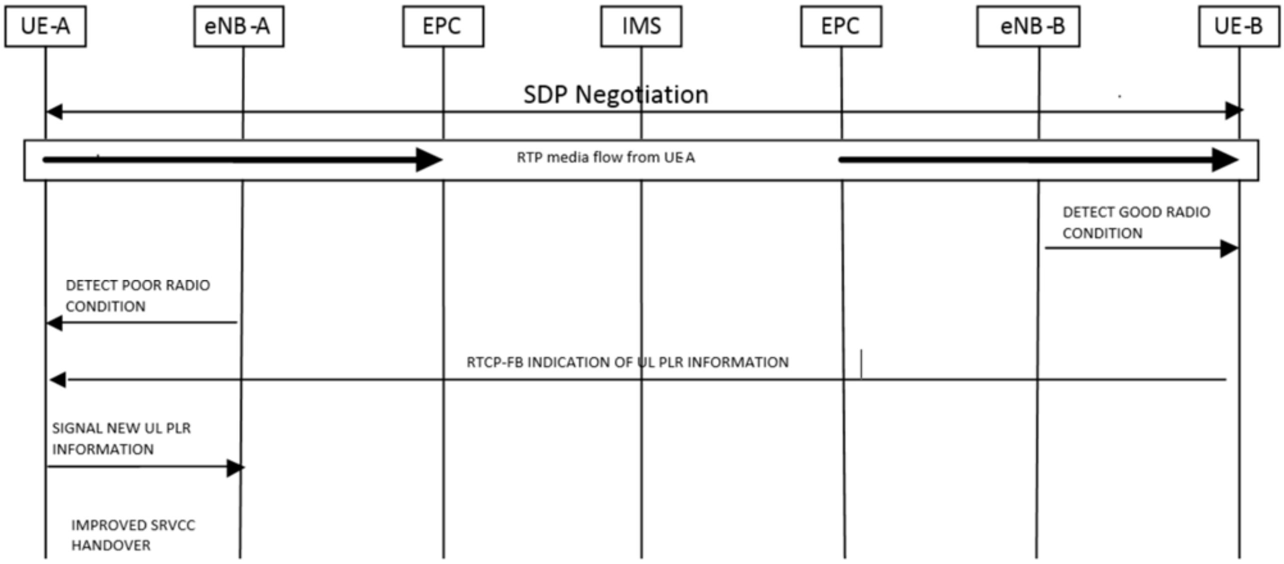


Figure 8.3: Examplary signaling flow for dynamic DL PLR and UL PLR allocation based on the use of RTCP feedback signaling

Step 1: UE-A and UE-B exchange SDP that includes information on (i) max_e2e_PLR on UE-A and UE-B., (ii) RTCP-based ability to signal UL PLR information as described above, (iii) RTP header extension based capability to exchange UL PLR information as described above. Following the SDP negotiation, it is possible that DL PLR and UL PLR values may be statically configured and the respective SRVCC thresholds may be determined, as per the UE-based and network-based approaches documented in clauses 8.2.2.3 and 8.2.3.3 to 8.2.3.5, respectively. For instance, from the perspective of UE B, this means, eNB_B_DL_PLR and eNB_A_UL_PLR are also statically set.

Step 2: UE-A sends RTP media flow to UE-B.

Step 3: UE-B detects DL good radio conditions locally, e.g. UE-B measures low BLER over the local radio link. Hence, UE-B concludes that the local radio conditions will support the most robust codec mode with negligibly small PLR, and the chances of SRVCC handover are quite small.

Step 4: On the contrary, UE-A detects UL poor radio conditions locally, e.g. UE-A measures high BLER over the local radio link. Hence, UE-A concludes that the local radio conditions may hardly support the most robust codec mode, and there's a good chance that SRVCC handover will need to be triggered.

Step 5: UE-B sends to UE A an RTCP feedback message including UL PLR information, where eNB_A_UL_PLR value is set to a value almost close to max_e2e_PLR for UE B.

Step 6: UE A signals the new UL PLR value to eNB A. Then eNB updates its SRVCC handover threshold based on the new UL PLR value, which is higher than the statically set UL PLR value.

Step 7: SRVCC handover over the UL connection from UE A to eNB A is delayed further due to the dynamically signalled UL PLR information from UE B.

Next, we evaluate the potential performance enhancement based on the dynamic allocation of DL PLR and UL PLR compared to a static PLR allocation policy, considering the Example Maximum End-to-end Packet Loss Rate (PLR) per link values for AMR-WB and EVS as given in Table 5.1.

In the examples below, we distinguish between poor coverage UEs and good coverage UEs depending on their coverage conditions. Both kinds of UEs will be encountered in a typical cellular deployment. A poor coverage UE is typically located far from the eNB, e.g. at the cell edge, while a good coverage UE is typically located close to the eNB, e.g. at cell center. For a good coverage UE, it is considered that the most robust codec mode will be supported with negligibly small PLR, while for a poor coverage UE, PLR budget is critical and even the most robust codec mode may not be supported below the DL/UL PLR values set at the corresponding eNBs necessitating to trigger SRVCC handover.

NOTE: The dynamic PLR thresholds offered by the UEs are based on the PLR statistics observed over time.

Example 1: Sender in Poor Coverage (UL), Receiver in Good Coverage (DL)

- EVS and EVS-CA are negotiated as codecs for the session. Thus, MaxPLR for the end-to-end connection is 9%, as per Table 5.1.

- Consider two static PLR allocation schemes for reference toward the performance comparison. A 50-50 static PLR allocation policy would set both DL PLR and UL PLR to 4.5%. A 70-30 static allocation policy would set DL PLR to 2.7% and UL PLR to 6.3%.

- Due to very poor coverage on the sender side, EVS-CA mode needs to be used based on the MTSI client adaptation. In the meantime, due to the good DL coverage conditions, the receiver can receive the voice packets at a negligibly small PLR from its eNB. Thus, most of the end-to-end PLR budget may be allocated to UL PLR. As such, UL PLR can be set to close to 9% by the dynamic allocation policy. To make this allocation happen, the poor coverage UE makes a request by signaling the UL PLR value close to 9%, say 8.5% (or a corresponding UL/DL ratio value, say 20 or higher) to the good coverage UE, and then the good coverage UE agrees to this PLR allocation and signals back accordingly. It should be noted that by default eNBs would use the statically configured PLR thresholds in case there is no agreement between the UEs on the dynamic PLR allocation, among the UEs. Upon agreement, the good coverage UE and bad coverage UE may then signal the agreed DL PLR and UL PLR values to their eNBs to configure the corresponding SRVCC handover thresholds.

- As such, the UL PLR as set by the dynamic allocation policy will help to sustain the LTE voice connection for a longer amount of time, and delay the SRVCC handover until the UL PLR exceeds 8.5%. On the contrary, the static allocation policy would have triggered SRVCC when the UL PLR exceeded 4.5% (under the 50-50 allocation) or 6.3% (under the 70-30 allocation). This demonstrates the potential performance enhancement from the use of a dynamic PLR allocation framework over static PLR allocation.

- For static (non-moving) UEs, channel conditions will tend to persist for a long period of time. As such, once the UL and DL PLR values have been set as per the dynamic allocation policy, there is no need to change them for a long period of time, potentially for the entire duration of the voice call.

- For mobile (moving) UEs, the channel conditions will vary over time, and as such it will be necessary to update the dynamic PLR allocation values over time. However, given the even for moving UEs, the frequency of the PLR updates are expected to be manageable during the course of the MTSI voice session.

Example 2: Sender in Good Coverage (UL), Receiver in Poor Coverage (DL)

- EVS and EVS-CA are negotiated as codecs for the session. Thus, MaxPLR for the end-to-end connection is 9%, as per Table 5.1.

- Consider two static PLR allocation schemes for reference toward the performance comparison. A 50-50 static PLR allocation policy would set both DL PLR and UL PLR to 4.5%. A 70-30 static allocation policy would set DL PLR to 2.7% and UL PLR to 6.3%.

- Due to very poor coverage on the receiver side, EVS-CA mode needs to be used based on the MTSI client adaptation. In the meantime, due to the good UL coverage conditions, the sender can transmit the voice packets at a negligibly small PLR to its eNB. Thus, most of the end-to-end PLR budget may be allocated to DL PLR. As such, DL PLR can be set to ~9% by the dynamic allocation policy. To make this allocation happen, the poor coverage UE makes a request by signaling the UL PLR value close to 0%, say 0.5% (or a corresponding UL/DL ratio value, say 0.05 or lower) to the good coverage UE, and then the good coverage UE agrees to this PLR allocation and signals back accordingly. The good coverage UE and bad coverage UE may then signal the agreed DL PLR and UL PLR values to their eNBs to configure the corresponding SRVCC handover thresholds.

- As such, the DL PLR as set by the dynamic allocation policy will help to sustain the LTE voice connection for a longer amount of time, and delay the SRVCC handover until the DL PLR exceeds 8.5%. On the contrary, the static allocation policy would have triggered SRVCC when the DL PLR exceeded 4.5% (under the 50-50 allocation) or 2.7% (under the 70-30 allocation). This demonstrates the potential performance enhancement from the use of a dynamic PLR allocation framework over static PLR allocation.

- For static and mobile UEs, the same considerations as in Example 1 above apply. As such, once the UL and DL PLR values have been set as per the dynamic allocation policy, there is no need to change them for a reasonably long period of time and the frequency of PLR updates is expected to be low.

Example 3: Sender in Poor Coverage (UL), Receiver in Poor Coverage (DL)

- EVS and EVS-CA are negotiated as codecs for the session. Thus, MaxPLR for the end-to-end connection is 9%, as per Table 5.1.

- Consider two static PLR allocation schemes for reference toward the performance comparison. A 50-50 static PLR allocation policy would set both DL PLR and UL PLR to 4.5%. A 70-30 static allocation policy would set DL PLR to 2.7% and UL PLR to 6.3%.

- Due to very poor coverage on both the sender and receiver sides, EVS-CA mode needs to be used based on the MTSI client adaptation. End-to-end PLR budget needs to be allocated very carefully between DL PLR and UL PLR as SRVCC may be triggered on both ends due to poor coverage conditions and determining the optimal DL PLR and UL PLR can help to sustain the LTE voice connections on both ends for a longer amount of time.

- As part of the dynamic PLR allocation, both UEs will seek to use from the available end-to-end PLR budget as much as possible. As such, it is likely that both UEs will request a significant portion from the available end-to-end PLR budget. This may lead to back and forth exchanges between the UEs on the dynamic PLR allocation. The UEs may agree on a DL and UL PLR allocation that will fulfil the PLR demands on both links. In case of no agreement, a fallback to the static PLR allocation policy would be more suitable in this scenario.

Example 4: Sender in Good Coverage (UL), Receiver in Good Coverage (DL)

- EVS and EVS-CA are negotiated as codecs for the session. Thus, MaxPLR for the end-to-end connection is 9%, as per Table 5.1.

- Consider two static PLR allocation schemes for reference toward the performance comparison. A 50-50 static PLR allocation policy would set both DL PLR and UL PLR to 4.5%. A 70-30 static allocation policy would set DL PLR to 2.7% and UL PLR to 6.3%.

- Due to good coverage conditions on both the sender and receiver sides, EVS mode is used based on the MTSI client adaptation. The likelihood of triggering SRVCC is quite small in this setting. As such, static PLR allocation and dynamic PLR allocation yield the same result.

Bi-Directional Communication Considerations

The relevant MTSI scenario of when one UE is in good coverage, say UE1, and other UE is in poor coverage, say UE2, is the combination of Examples 1 and 2 above. In particular, Example 1 would be applicable for the RTP media streamed from UE2 to UE1, and Example 2 would be applicable for the RTP media streamed from UE1 to UE2, as part of the MTSI voice call.

Table 8.4 illustrates the corresponding PLR allocations for the static PLR allocation (50:50 and 70:30) and dynamic PLR allocation strategies described in Examples 1 and 2. As such, SRVCC for the poor coverage UE (i.e. UE2) is governed by the DL PLR and UL PLR thresholds in the third and fourth rows of Table Z. It can be seen that dynamic PLR allocation strategy leads to a significant increase in the DL and UL PLR thresholds to serve as SRVCC triggers. In particular, for the poor coverage UE (UE2 in this example), the measured DL PLR and UL PLR values are likely to be high. As such, SRVCC would be triggered when measured DL PLR or UL PLR exceeds 4.5% in the 50:50 static PLR allocation scenario. Likewise, SRVCC would be triggered when measured DL PLR exceeds 2.7% or measured UL PLR exceeds 6.3% in the 70:30 static PLR allocation scenario. For dynamic PLR allocation, SRVCC would only be triggered when measured DL PLR or UL PLR exceeds 8.5%. This demonstrates that, compared to the static allocation strategies, the dynamic PLR allocation strategy will allow further delaying the SRVCC handover for the poor coverage UE, provided that the remote end UE experiences sufficiently good coverage.

Table 8.4: Comparison of Static and Dynamic PLR Allocation Strategies

Parameter	50:50 Static PLR Allocation	70:30 Static PLR Allocation	Dynamic PLR Allocation
DL PLR threshold at UE1 (Good Coverage UE)	4.5%	2.7%	Variable (0.5% for Examples 1 and 2)
UL PLR threshold at UE1 (Good Coverage UE)	4.5%	6.3%	Variable (0.5% for Examples 1 and 2)
DL PLR threshold at UE2 (Poor Coverage UE)	4.5%	2.7%	Variable (8.5% for Examples 1 and 2)
UL PLR threshold at UE2 (Poor Coverage UE)	4.5%	6.3%	Variable (8.5% for Examples 1 and 2)

Sample Timeline of Events with Static and Dynamic PLR Allocation

In Table 8.5, a sample timeline of events with static and dynamic PLR allocation strategies is presented based on the setup described in Examples 1-4, and resulting DL PLR and UL PLR thresholds presented in Table 8.4. The table presents a sample set of the measured DL PLR and UL PLR values on both ends of the link during an MTSI voice call between UE1 and UE2. In this example, UE1 is placed close to the eNB to have good coverage, while UE2 is farther away from the eNB to experience poor coverage. Measured DL PLR and UL PLR values for UE1 and UE2 were obtained in a system-level simulation environment considering the Urban Macrocell (UMa) deployment scenario of the IMT-Advanced evaluation methodology [7] with UE mobility at 3km/h, using a 2x2 antenna configuration for DL, 1x2 antenna configuration for UL and an inter-site distance (ISD) of 500m. Moreover, the simulation configuration was established based on the VoIP evaluation methodology of [7].

For the dynamic PLR allocation, the agreed UL/DL PLR ratios in the two directions are also presented. The first UL/DL PLR ratio number in the table is for UL PLR at UE2 and DL PLR at UE1, and the second UL/DL PLR ratio number is for UL PLR at UE1 and DL PLR at UE2.

For the 50:50 static PLR allocation policy, based on the PLR thresholds in Table 8.4, SRVCC is triggered at time = 2s. For the 70:30 static PLR allocation policy, based on the PLR thresholds in Table 8.4, SRVCC is triggered at time = 6s. The dynamic PLR allocation is able to adaptively select the UL/DL PLR ratios with varying link conditions and is able to avoid SRVCC during the entire 10s period. In this case, given the extremely good DL/UL coverage conditions for UE1, SRVCC is avoided by maintaining the same dynamic PLR allocation over the entire 10s period.

Table 8.5: Sample Timeline with Static and Dynamic PLR Allocation Strategies

Parameter	Time =2 s	Time = 4s	Time = 6s	Time = 8s	Time = 10s
Measured DL PLR at UE1	0%	0%	0%	0%	0%
Measured UL PLR at UE1	0%	0%	0%	0%	0%
Measured DL PLR at UE2	2.7%	2.2%	5.9%	3%	2%
Measured UL PLR at UE2	4.6%	2.6%	6.7%	5.2%	3.7%
Outcome of 50:50 Static PLR Allocation	**SRVCC triggered**				
Outcome of 70:30 Static PLR Allocation	No SRVCC triggered	No SRVCC triggered	**SRVCC triggered**		
Outcome of Dynamic PLR Allocation	Agree on 80:20 & 20:80, **No SRVCC triggered**	Maintain 80:20 & 20:80, **No SRVCC triggered**	Maintain 80:20 & 20:80, **No SRVCC triggered**	Maintain 80:20 & 20:80, **No SRVCC triggered**	Maintain 80:20 & 20:80, **No SRVCC triggered**

In Table 8.6, another sample timeline of events with static and dynamic PLR allocation strategies is presented based on the setup described in Examples 1-4, and resulting DL PLR and UL PLR thresholds presented in Table 8.4. In this example, both UE1 and UE2 are assumed to experience coverage issues. Otherwise, the same simulation setup used to generate the results in Table 8.5 was used.

For the dynamic PLR allocation, the agreed UL/DL PLR ratios in the two directions are also again presented. The first UL/DL PLR ratio number in the table is for UL PLR at UE2 and DL PLR at UE1, and the second UL/DL PLR ratio number is for UL PLR at UE1 and DL PLR at UE2. To consider as few configurations as possible, UL/DL PLR ratios are constrained such that the numerator and denominator values are to be multiples of 10, i.e. leading to configurations such as 50:50, 40:60, 30:70, etc.

For the 50:50 static PLR allocation policy, based on the PLR thresholds in Table 8.4, SRVCC is triggered at time = 2s. For the 70:30 static PLR allocation policy, based on the PLR thresholds in Table 8.4, SRVCC is triggered at time = 6s. The dynamic PLR allocation is able to adaptively select the UL/DL PLR ratios with varying link conditions and is able to avoid SRVCC during the first 8s. During time=10s, none of the constrained UL/DL PLR ratios would lead to SRVCC PLR thresholds that fall below the measured PLR values, and hence SRVCC is triggered. Otherwise, an UL/DL PLR allocation of (45:55) & (70:30) could have prevented SRVCC at time=10s as well.

Table 8.6: Another Sample Timeline with Static and Dynamic PLR Allocation Strategies

Parameter	Time =2 s	Time = 4s	Time = 6s	Time = 8s	Time = 10s
Measured DL PLR at UE1	2.2%	2%	1.8%	3.5%	4.6%
Measured UL PLR at UE1	3.6%	3.5%	2.4%	3.4%	6.3%
Measured DL PLR at UE2	2.7%	2.2%	5.9%	3%	2%
Measured UL PLR at UE2	4.6%	2.6%	6.7%	5.2%	3.7%
Outcome of 50:50 Static PLR Allocation	**SRVCC triggered**				
Outcome of 70:30 Static PLR Allocation	No SRVCC triggered	No SRVCC triggered	**SRVCC triggered**		
Outcome of Dynamic PLR Allocation	Agree on 70:30 & 50:50, **No SRVCC triggered**	Maintain 70:30 & 50:50, **No SRVCC triggered**	Agree on 80:20 & 30:70, **No SRVCC triggered**	Agree on 60:40 & 50:50, **No SRVCC triggered**	**SRVCC triggered**

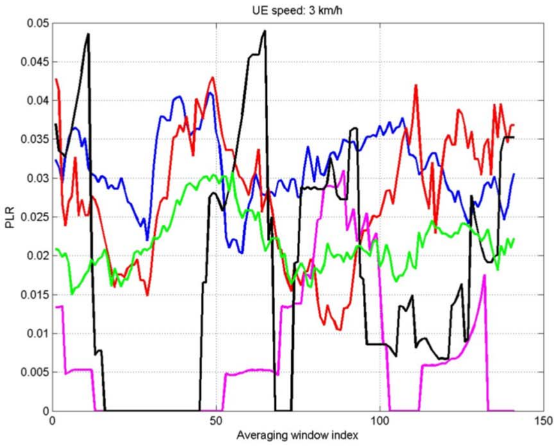
Implications on Signalling Frequency:

The relevant question in this context is to understand what kind of signalling frequency would be required to realize such dynamic PLR allocation strategies. As described by the examples above, the scenario when the dynamic PLR allocation leads to a performance improvement over the static PLR allocation in an MTSI call is when one UE experiences poor coverage while the other UE experiences good coverage.

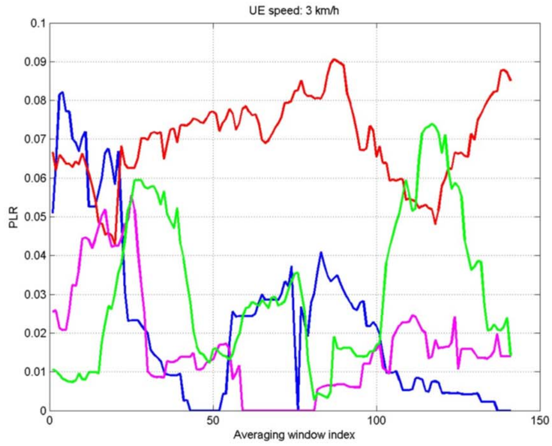
If the UEs are static, such coverage conditions tend to persist for a long time, i.e. potentially for the entire duration of the MTSI voice session. If the UEs are mobile, the coverage conditions may vary over time, depending on the UE mobility. Even in this case however, the same coverage conditions on average will persist in the order of a few seconds considering the various mobility levels of the IMT Advanced evaluation methodology [7], i.e. speeds of 3 km/h and 30 km/h for the Urban Macrocell (UMa) and 120 km/h for the Rural Macrocell (RMa) deployment models.

Figure 8.2.2 contains the simulated DL PLR curves based on the IMT-Advanced evaluation methodology [7] for the various UEs experiencing PLRs in the range of 1%-10%, at mobility levels 3 km/h (UMa), 30 km/h (UMa) and 120 km/h (RMa). The simulation configuration was established based on the VoIP evaluation methodology of [7]. The system operates close to its VoIP capacity with 50, 44 and 38 VoIP UEs per sector per MHz for 3, 30 and 120 km/h, respectively. Most of the other UEs experience PLRs close to 0 (these were not plotted) for the entire duration of the simulation. In particular, on average, 96.3% of the UEs experience 0% PLR, 2.1% of the UEs experience PLRs in the range of 0-10% and 1.6% of the UEs experience PLRs above 10%. The averaging window size for PLR measurements is 5 seconds long, the window slide to update PLR estimates is 0.25 seconds and the total simulation time is 40 seconds. A 2x2 DL antenna configuration and an inter-site distance (ISD) of 500m were considered.

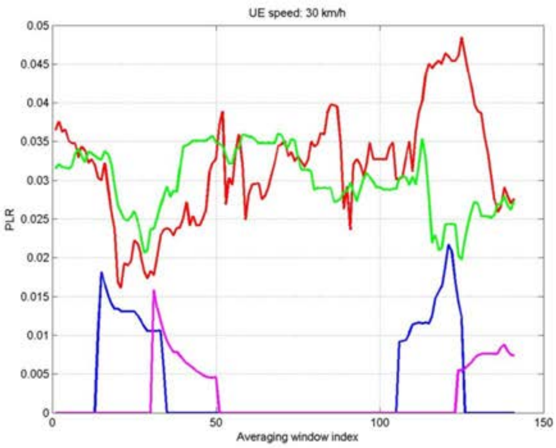
It can be observed from the plots that the same coverage conditions on average will persist in the order of several seconds considering all three mobility levels. As such, when a UE agrees on a certain dynamic PLR allocation, it can be expected that this agreed-upon PLR allocation can be maintained for at least several seconds for all of the mobility levels. In other words, if an MTSI voice session is established between a poor coverage UE and a good coverage UE, and the DL/UL PLR thresholds for SRVCC at the respective eNBs are chosen based on the a dynamic PLR allocation policy, it is highly likely that these DL/UL PLR thresholds may be sustained in the order of several seconds without the need for any additional signalling to modify the agreed-upon PLR allocation, since the good coverage UE will remain in good coverage, and poor coverage UE will remain in poor coverage with similar range of PLR variations. Hence, it is concluded that the frequency of the PLR updates and signaling necessary to realize the dynamic PLR allocation strategies described above are in the order of several seconds and therefore are expected to be manageable during the course of the MTSI voice session.



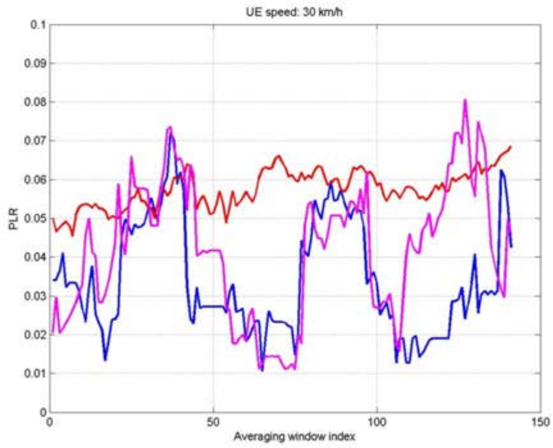
(a)



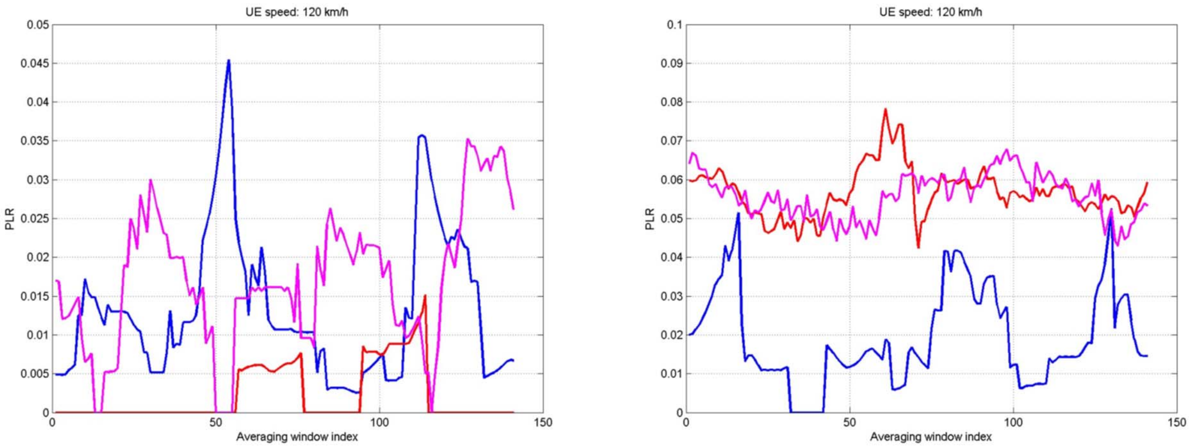
(b)



(c)



(d)



(e) (f)

Figure 8.4: Simulated PLR curves for various mobility levels, 3 km/h, 30 km/h, and 120 km/h

8.2.3 Network-requested UL and DL PLR

8.2.3.1 General

In the following set of solutions, after the exchange of the required max_e2e_PLR in each transmission direction, the UEs or the network determine what maximum PLR is needed for the uplink and downlink (Figure 8.5). Then the network sends the required maximum UL PLR and DL PLR values to the eNBs using messages that would be specified in SA2.

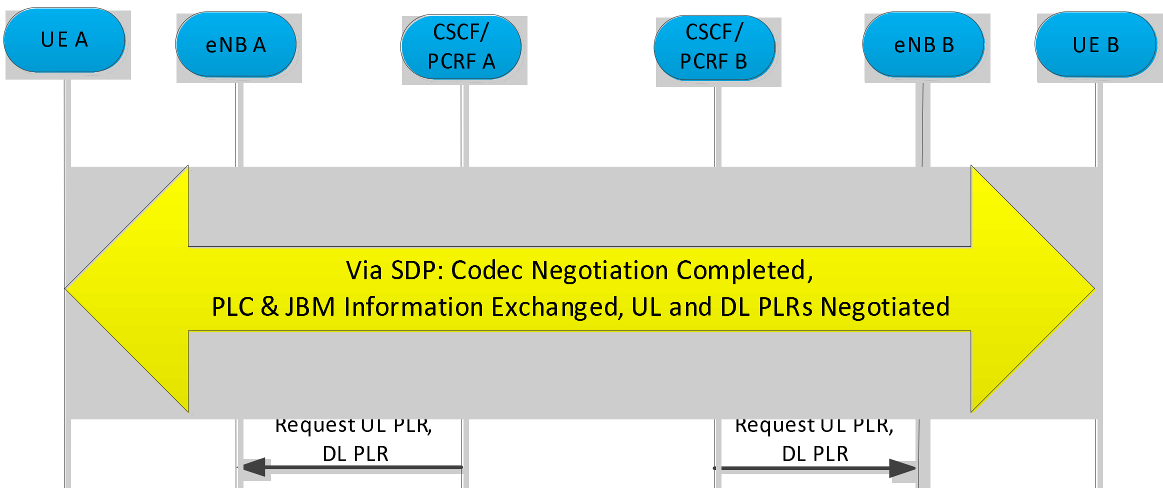


Figure 8.5: Network-requested UL PLR and DL PLR

How the UEs and networks can determine the UL PLR and DL PLR to request of each eNB is described in the following clauses. One distinction to observe among the potential solutions is whether (i) the UL PLR and DL PLR are set statically at the session level and kept the same regardless of the local RAN conditions as in clauses 8.2.3.2 to 8.2.3.5, or (ii) the UL PLR and DL PLR are dynamically allocated according to the local RAN conditions on both ends of the link, as in clause 8.2.3.6.

8.2.3.2 Simple Ratio

This follows the same principle as in clause 8.2.2.2 where a ratio of UL PLR: DL PLR is configured or agreed among the PCRFs. Based on this ration the PCRFs can allocate the appropriate proportion of max_e2e_PLR to their local eNB's uplink and downlink. If UL PLR: DL PLR = R then:

- PCRF A asks its eNB to support on its uplink, UL_PLR_A = (max_e2e_PLR_B) [R /(R+1)]
- PCRF A asks its eNB to support on its downlink, DL_PLR_A = (max_e2e_PLR_A) [1 /(R+1)]
- PCRF B asks its eNB to support on its uplink, UL_PLR_B = (max_e2e_PLR_A) [R /(R+1)]
- PCRF B asks its eNB to support on its downlink, DL_PLR_B = (max_e2e_PLR_B) [1 /(R+1)]

8.2.3.3 SDP-Negotiated

This follows the same principle as in clause 8.2.2.3 where the UEs negotiate the proportion of the max_e2e_PLR to their local eNB's uplink and downlink. However, instead of having the UEs request the resulting uplink and downlink PLRs directly from the eNBs, the CSCF/PCRFs examine the SDP answer to extract the negotiated PLR configuration and communicate the appropriate values to their local eNBs.

For example, if UE A is the offerer and UE B is the answerer then the PCRFs would perform the following with SDP parameters included SDP answer:

- PCRF A asks its eNB to support on its uplink, UL_PLR_A = UL_PLR_Off (the value included in the SDP answer)
- PCRF A asks its eNB to support on its downlink, DL_PLR_A = DL_PLR_Off (the value included in the SDP answer)
- PCRF B asks its eNB to support on its uplink, UL_PLR_B = UL_PLR_Ans
- PCRF B asks its eNB to support on its downlink, DL_PLR_B = DL_PLR_Ans

8.2.3.4 PCRF-Negotiated

This is similar to the approach described in clause 8.2.3.3 except that the negotiation of what proportion of the max_e2e_PLR to allocate to the eNBs uplinks and downlinks is performed by CSCFs/PCRFs as follows:

- UE A (the offerer) in its SDP offer indicates its max_e2e_PLR_Off.
- CSCF/PCRF A sees this parameter value and based on operator policy, decides how it would prefer to allocate a proportion of max_e2e_PLR_Off across the downlink of eNB A and indicates this by adding DL_PLR_Off in the SDP offer.
- CSCF/PCRF A also indicates its preferred uplink PLR by adding UL_PLR_Off into the offer.
- CSCF/PCRF B stores the values of DL_PLR_Off and UL_PLR_Off in the SDP offer and removes these SDP parameters from the SDP offer before forwarding this onto UE B.
- UE B receives the SDP offer, and responds by including its max_e2e_PLR_Ans in the SDP answer it sends back.
- CSCF/PCRF B receives the SDP answer, and checks that, DL_PLR_Ans, plus UL_PLR_Off is less than max_e2e_PLR_Ans.
    - If this condition is met then CSCF/PCRF B adds DL_PLR_Ans and UL_PLR_Off into the SDP Answer.
    - Otherwise, CSCF/PCRF B modifies both DL_PLR_Ans and UL_PLR_Off so that their sum is less than max_e2e_PLR_Ans, then includes them into the SDP answer.
- Similarly, CSCF/PCRF A checks that, UL_PLR_Ans, plus DL_PLR_Off is less than max_e2e_PLR_Off:
    - If this condition is met then CSCF/PCRF A adds UL_PLR_Ans and DL_PLR_Off into the SDP Answer.
    - Otherwise, CSCF/PCRF B modifies both UL_PLR_Ans and DL_PLR_Off so that their sum is less than max_e2e_PLR_Off, then includes them into the SDP answer.
- When CSCF/PCRF A receives the SDP answer it may reject it if the values of UL_PLR_Off and DL_PLR_Off that were modified by CSCF/PCRF B are not acceptable. If CSCF/PCRF A accepts the SDP answer then both

CSCF/PCRF A and CSCF/PCRF B have all the information they need to communicate the required UL and DL PLRs to their local eNBs.

8.2.3.5 PCRF-Negotiated using single SDP parameter

In this approach only a single SDP parameter, max_e2e_PLR, is defined and used. In the description below the "_A" and "_B" extensions are added to make it easier to understand what is being described. In the actual SDP only the max_e2e_PLR parameter needs to be used.

The procedures are as follows:

- UE A sends its max_e2e_PLR_A in the SDP offer.
- CSCF/PCRF A sees this parameter in the SDP offer and decides that it will allocate on the downlink to UE A DL_PLR_A which is less than max_e2e_PLR_A.
- CSCF/PCRF A also modifies the parameter in the SDP offer to indicate a:
  - new max_e2e_PLR_A = old max_e2e_PLR_A – DL_PLR_A.
- This modified SDP offer is sent to the CSCF/PCRF B.
- CSCF/PCRF B uses the modified max_e2e_PLR_A value in the SDP offer to set the uplink PLR at eNB B, UL_PLR_B = new max_e2e_PLR_A. CSCF/PCRF B could also choose to use a UL_PLR_B < new max_e2e_PLR_A if it did not want to use the entire e2e PLR budget.

In the reverse direction a similar procedure happens:

- UE B sends its max_e2e_PLR_B in the SDP answer.
- The local CSCF/PCRF B takes a portion of max_e2e_PLR_B and allocates it to the downlink of eNB B in DL_PLR_B.
- CSCF/PCRF B modifies the max_e2e_PLR_B in the SDP answer to new max_e2e_PLR_B = old max_e2e_PLR_B – DL_PLR_B
- CSCF/PCRF B then sends this new max_e2e_PLR_B value to CSCF/PCRF A.
- CSCF/PCRF A uses the new max_e2e_PLR_B value in the SDP answer to set the uplink PLR at eNB A, UL_PLR_A = new max_e2e_PLR_B. CSCF/PCRF A could also choose to use a UL_PLR_A < new max_e2e_PLR_B if it did not want to use the entire e2e PLR budget.

8.2.3.6 Dynamic Allocation of UL PLR and DL PLR

The network-requested DL and UL PLR framework as described above leads to static allocation and configuration of DL PLR and UL PLR values. If such a framework is used, the respective eNBs may determine the SRVCC thresholds based on these PLR values as configured by the network.

On top of this, the UE-based signaling described in clause 8.2.2.4 may be used to dynamically exchange information on UL PLR and DL PLR allocation between the UEs and signal this information to the respective eNBs. The eNBs may then override the SRVCC thresholds based on the dynamically signaled PLR information from the UEs. As such, it would be possible to dynamically optimize the allocation of DL PLR and UL PLR values, which leads to the most optimal selection of the SRVCC handover thresholds on both ends of the link.

8.3 Conclusion

This Clause evaluated the benefits of two types of functionality for realizing codec-aware SRVCC enhancements:

1) SDP-based signalling of max_e2e_PLR, DL/UL PLR (or PLR ratio) values considering the potential solutions as per clauses 8.2.2.3, 8.2.3.3.
2) RTP/RTCP-based indication of recommended DL/UL PLR (or PLR ratio) values considering the potential solutions as per clauses 8.2.2.4 and 8.2.3.6.

Both of these approaches improve the selection of the DL/UL PLR thresholds at the eNB for triggering SRVCC, by providing further enhancements on top of the determination of the DL/UL PLR threshold values at the PCRF based on the negotiated codecs and codec modes (as described in clauses 4.2.1 and 5.2.1).
SDP-based signalling of max_e2e_PLR allows for considering the receiving UE capabilities including, for example, jitter buffer management (JBM) and packet loss concealment (PLC), in addition to the negotiated codecs and codec modes. As such, for an MTSI session involving bidirectional media communication between two UEs, different max_e2e_PLR values may be negotiated for each of the two media streams depending on each UE's JBM and PLC capabilities. This also helps choose the DL/UL PLR thresholds for SRVCC differently at the eNBs depending on the negotiated max_e2e_PLR values.

The RTP/RTCP-based indication of the recommended DL/UL PLR (or PLR ratio) values realizes a dynamic PLR allocation framework on DL PLR and UL PLR thresholds. This framework enables further optimizations of the SRVCC thresholds for DL and UL after initial setting of the DL PLR and UL PLR thresholds at the eNB based on the signalling from the PCRF. The dynamic PLR allocation realizes this enhancement by adapting the DL PLR and UL PLR thresholds to the local RAN conditions considering UE coverage, leading to the SRVCC performance improvements as documented in clause 8.2.2.4.

NOTE: SDP-based signalling of max_e2e_PLR, DL/UL PLR (or PLR ratio) requires CT1/3/4 and SA2 support. RTP/RTCP-based indication of recommended DL/UL PLR (or PLR ratio) values requires RAN2 support.

9 Conclusions

Based on the Conclusions in clauses 5.3, 6.3, 7.3, and 8.3, it is recommended to conduct normative work to specify the following in TS 26.114:

1) Include in an annex MaxPLR operating points for different codecs considering the examples as per clauses 5.2 and 5.3 (see Annex X of 3GPP TS 26.114 [3]).

2) Adaptation capability indication (using a new SDP attribute) considering the potential solutions as per clauses 7.2 and 7.3 (see Annexes W.1, W.2, and W.3 of 3GPP TS 26.114 [3]).

3) SDP-based signalling of max_e2e_PLR, DL/UL PLR (or PLR ratio) values considering the potential solutions as per clauses 8.2.2.3, 8.2.3.3, 8.2.3.4, and 8.2.3.5 (see Annex W.4 of 3GPP TS 26.114 [3]).

4) RTP/RTCP-based indication of recommended DL/UL PLR (or PLR ratio) values considering the potential solutions as per clauses 8.2.2.4 and 8.2.3.6. This approach has not been pursued in the normative specification because of lack of the necessary RAN2 support.

NOTE: The above SDP-based signalling and RTP/RTCP-based indication requires CT1/CT3/CT4/SA2 and RAN2 support, respectively.

The recommendations on MaxPLR operating points for different codecs (bullet 1 above) serves at the center of the anticipated eVoLP capabilities in TS 26.114, for both the network-based and UE-based architectures described in clause 4.2. It is noted that among these architectures, the network-based architecture in clause 4.2.1 is already supported through the signalling from PCRF to eNB as defined in TS 23.203 and TS 23.401, and as such enables early deployments of eVoLP.

Among the three eVoLP functionalities listed in bullets 2, 3 and 4 above, it is expected that the adaptation capability indication will be mandatory for eVoLP-capable MTSI clients, while the remaining two functionalities will be defined as supplemental and left optional for eVoLP-capable MTSI clients. A key reason for this is that adaptation capability indication serves as a critical eVoLP functionality allowing the derivation of MaxPLR at the PCRF (in case of the network-based architecture) based on the most robust codec mode among the negotiated codecs and codec modes, while in the absence of this parameter the MaxPLR would have to be derived based on the least robust codec mode.

Adaptation capability indication and negotiation based on the SDP 'adapt' parameter (bullet 2 above) and SDP-based signalling of max_e2e_PLR, DL/UL PLR (or PLR ratio) values (bullet 3 above) would lead to definition of new SDP parameters in TS 26.114, requiring core network support. RTP/RTCP-based indication of recommended DL/UL PLR (or PLR ratio) values (bullet 4 above) would lead to definition of *conceptual message* formats between the UE and eNB in TS 26.114 (similar to the *conceptual message* formats for ANBR in TS 26.114), requiring RAN support toward determining the exact message mapping, e.g. for LTE or NR access. As such, upon completion of normative work in TS

26.114, it is expected that these core network and RAN dependencies will also have to be addressed in coordination with the relevant 3GPP working groups.

Figure 9.1 illustrates the relationships between the core functionality and different optional enhancements specified in the normative feature "Coverage and Handoff Enhancements for Multimedia" (CHEM) in Annex W of TS 26.114. Clauses W.1 and W.2 specify the basic core functionality, the minimum requirement, needed to use the CHEM feature. Clause W.4 specifies the optional enhancement to negotiate the end-to-end PLR values on both the uplink and downlink of each MTSI client. Clause W.3 specifies the another optional enhancement to use application layer redundancy to improve media robustness and use specifically-scoped in-band RTP CMR codepoints to request application layer redundancy.

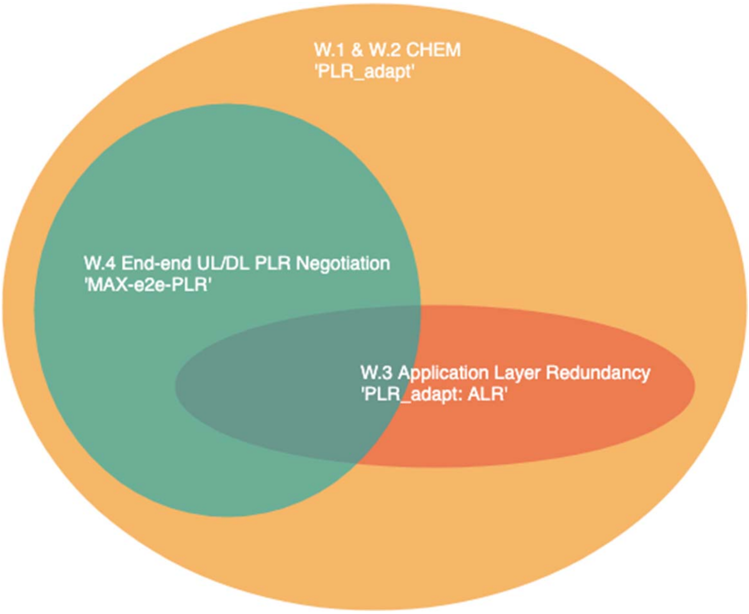


Figure 9.1: Core function and optional enhancements of the normative feature "Coverage and Handoff Enhancements for Multimedia (CHEM)". References are to clauses in 3GPP TS 26.114.

Annex A: Informal Objective and Subjective Experiments for Obtaining Max. PLR Operating Points with and without Application Layer Redundancy

Experiment A.1

MOS LQO statistics of certain example codec operating points as per Table 5.1 in clause 5.2.1.1 are presented in Figure A.1. The ITU-T P.863.1 recommendation is used to generate the MOS-LQO statistics over Clean speech (North American English database, 4 male, 4 female talkers, 5 sentences pairs (8 sec) per talker), over frame erasure rates of 3%-10%.

VoLTE Delay loss profiles 7, 8, 9, and 10 that were used in EVS Characterization testing (TR 26.952, Experiment S1) are used to obtain the MOS-LQO statistics for EVS 13.2 SWB, 13.2 CA SWB Offset 3, 2x7.2, 2x13.2, 2x13.2 CA, and IO 23.85. The experiment includes 100% application layer redundancy with Offset 2, resulting in 2xbitrate.

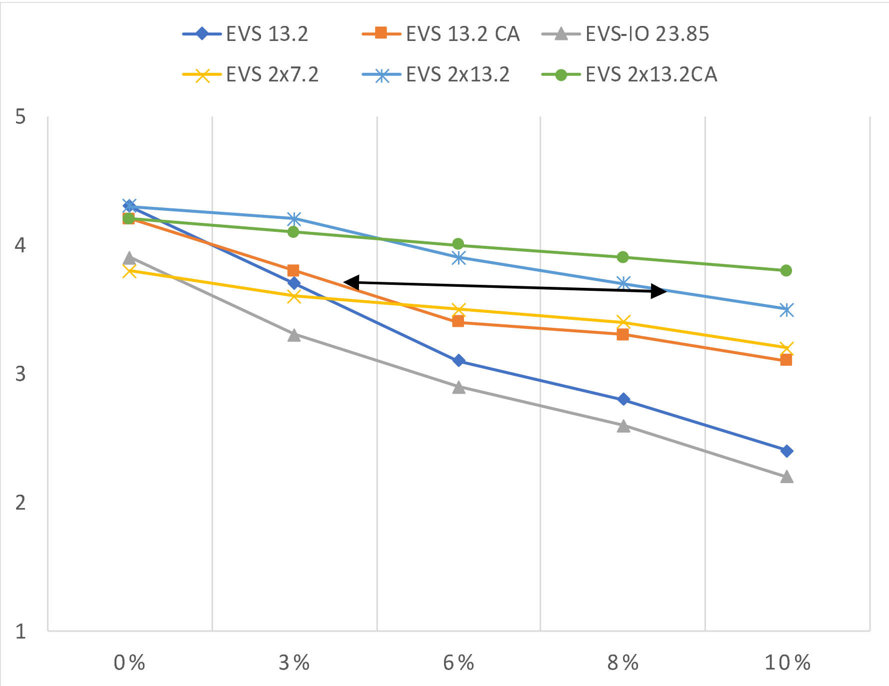


Figure A.1: ITU-T P.863.1 MOS-LQO statistics of different codec operating points (as per Table 5.1) at different FER ranges with and without application layer redundancy

Experiment A.2

Unlike Experiment A.1 that was based on the VoLTE delay profiles, this experiment was based on random channel errors (at FER of 3, 6, 9, and 12%) without Jitter from EVS qualification scripts. The simulation included 100% application-layer redundancy (offset=2). Loss patterns were generated as in EVS qualification with the 'gen-patt' tool from ITU-T STL with gamma=1 (i.e. Gilbert model operated with random errors and no memory). Packet loss patterns used a random generation with a uniform i.i.d distribution, therefore the performance with 100% application-layer redundancy at PLR rate p corresponds to the performance without redundancy at PLR rate p^2 (in the asymptotic case). This is a conservative case as it does not include the Jitter and other bursty channel characteristics of a VoLTE profile.

As an example EVS configuration with br=9.6-24.4 kbit/s, bw=swb, one may enable the 2*9.6 kb/s (redundancy) condition in the allowed bearer. For other configurations, e.g. br=5.9-24.4, bw=nb-swb, the application layer redundancy can exercise many different options, e.g. 2x5.9, 3x5.9, 2x7.2, 3x7.2, 2x8, 3x8, and 2x9.6 within the allowed bearer.

From Figure A.2 the maximum PLR operating point with application layer redundancy is about 3% more than without application layer redundancy (i.e. 9.6 kbps at 6% FER and 24.4 kbps at 3% FER). This analysis does not take into account the corresponding path loss characteristics at higher bitrates and is a conservative estimate.

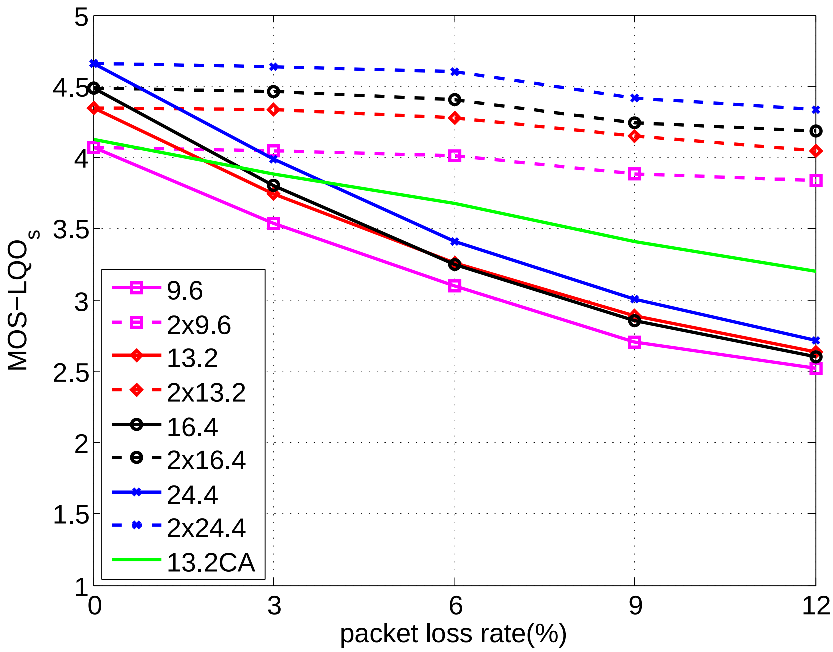


Figure A.2: Test results for EVS Primary (SWB) performance in loss conditions, with and without application-layer redundancy

Experiment A.3.

The P.800 ACR test methodology was used to study the Max. PLR operating points with application layer redundancy in addition to the objective experiments A.1 and A.2.

The test included 48 conditions and used Listening level at 73 dB SPL (diotic listening with Sennheiser 380Pro), 48 naive listeners (6 panels of 8 listeners), 24 clean speech samples with 4 talkers and 6 samples per talker. Further the test included 1152 processed sequences with 24 blocks for 6 panels (of 8 listeners), 4 blocks per panel. Each block contained 48 conditions and 4 talkers equally.

The number of votes per condition was 4 x 48 = 192. The overall listening/scoring duration was around 42 min for each subject (192 x approx. 13s), without the training session (12 samples) and breaks. Only random loss conditions (with no memory) were used with the following target PLR: noisy1 at 3%, noisy2 at 6%, noisy3 at 9%, and noisy4 at 12%.

The processing was done by extending EVS qualification scripts (Experiment J for SWB with noisy channel). The EVS codec was the latest fixed-point version (TS 26.442 v14.1). The overall number of processing frames was 10,100 (24*8*50 frames of speech, with a 10s silence preamble accounting for 500 frames). All EVS test conditions had DTX activated (DTX on). Application-layer redundancy was applied only to active frames.

The EVS encoding algorithm was not modified - only the bitstream output was changed by using an extra buffer (queue) of encoded frames outside the main encoding loop to produce a G.192-extended bitstream including 100% redundancy at a given offset. The EVS decoder was extended to use a fixed buffer with some extra delay to allow using redundant frame at a given offset; besides this modified bitstream pre-processing, the EVS decoding algorithm was not changed. In the test, the offset was set to 2 for both 100% application-layer redundancy and EVS 13.2 channel-aware (with FEC indicator set to HI).

A summary of test results for the experiment is provided in Figure A.3. This bar chart shows the average scores with 95% confidence intervals for all 48 conditions (with reference conditions followed by test conditions at 0, 3, 6, 9, 12% PLR). The 100% application-layer conditions are identified with the '2x' label.

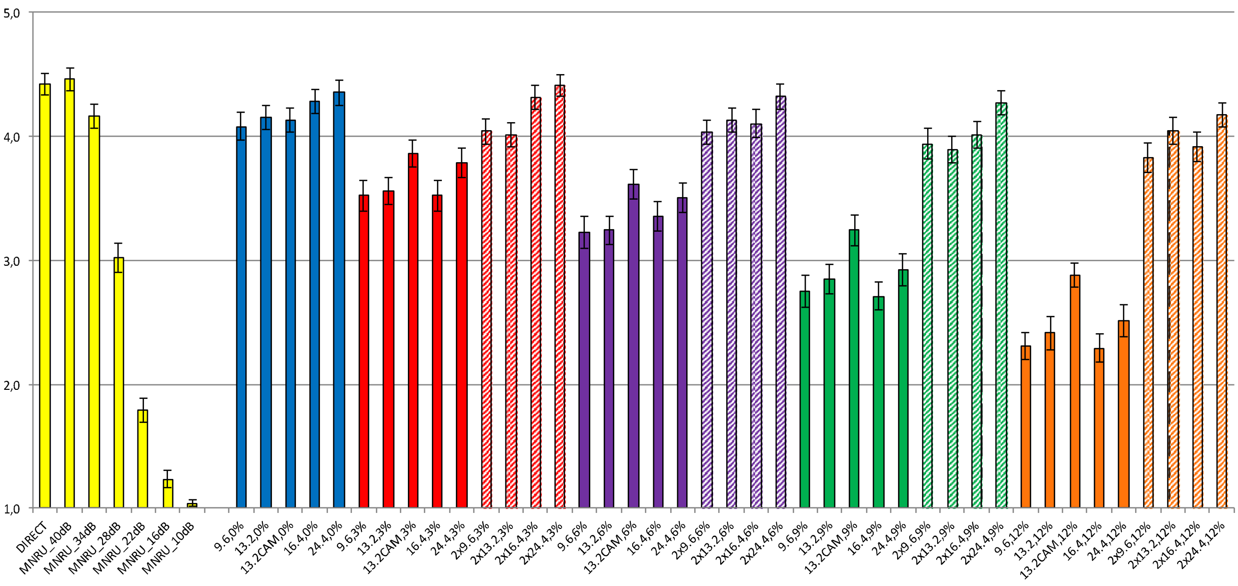


Figure A.3: P.800 ACR subjective test results (SWB, clean speech).

Observations from Experiment A.3:

The test is based on the P.800 ACR unlike the P.800 DCR subjective test methodology that was used in the EVS SWB qualification, selection and characterization testing. With the P.800 ACR test, EVS SWB conditions as shown in blue bar chart in Figure A.3 is providing a reduced subjective quality resolution. EVS at 2x7.2 kbps was not included in the test and cannot make a direct comparison to EVS 13.2 kbps or the most robust codec mode 13.2 kbps CA mode as per Table 5.1 for a similar bit rate. The channel conditions considered in this test were limited to random losses (with no memory). Further tests considering delay/loss profiles that reflect realistic VoLTE conditions are desirable. This will add other factors such as channel memory and the influence of jitter buffer with time scaling artifacts. Loss patterns were not constrained to be embedded as a function of increasing PLR, therefore slightly irregular MOS variation across PLR was expected.

Annex B: Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2017-12	78	SP-170833				Presented to TSG SA#78 for information	1.0.0
2018-06	SA#80	SP-180283				Presented to TSG SA#80 for approval	2.0.0
2018-06	SA#80					Approved at TSG SA#80 plenary meeting	15.0.0
2019-09	SA#85	SP-190652	0001	1	B	Updates based on CHEM feature	16.0.0

History

Document history		
V16.0.0	November 2020	Publication