3GPP TR 36.871 V11.0.0 (2011-12)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Evolved Universal Terrestrial Radio Access (E-UTRA);
Downlink Multiple Input Multiple Output (MIMO) enhancement for LTE-Advanced
(Release 11)

.

Keywords

LTE, MIMO

3GPP

Postal address

3GPP support office address

650 Route des Lucioles - Sophia Antipolis
Valbonne - FRANCE
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet

http://www.3gpp.org

Contents

Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

1 Scope

This TR collects the work done under the Study Item "Downlink MIMO Enhancement for LTE-Advanced" [2].

2 References

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

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

[2] RP-111366: Study Item Description for Downlink MIMO Enhancement for LTE-Advanced

[3] RP-111365: Work Item Description for Coordinated Multi-Point Operation for LTE

[4] R1-112091: Discussion on Real-Life DL MIMO Issues

[5] R1-113178: Real-life measurements on rank adaptation

[6] R1-113610: LS on Antenna Port Mapping onto Geographically Separated Antennas

[7] R1-113157: Summary of email discussion on enhanced PDCCH

[8] RP-111115: Work Item Description for CA Enhancements for LTE

[9] R1-114474: DL MIMO enhancement evaluation results

3 Definitions, symbols and abbreviations

Delete from the above heading those words which are not applicable.

Clause numbering depends on applicability and should be renumbered accordingly.

3.1 Definitions

For the purposes of the present document, the terms and definitions given in 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 TR 21.905 [1].

Definition format (Normal)

<defined term>: *<definition>.*

Example: text used to clarify abstract rules by applying them literally.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

Symbol format (EW)

<symbol> <Explanation>

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 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 TR 21.905 [1].

CoMP	Coordinated Multi-Point
CRS	Cell-specific Reference Signal
CSI	Channel State Information
DM-RS	DeModulation Reference Signal
ePDCCH	enhanced PDCCH
MU-MIMO	Multi-User Multiple-Input Multiple-Ouput
PDCCH	Physical Downlink Control CHannel
RI	Rank Indicator
RRH	Remote Radio Head

4 Objectives of the Downlink MIMO Enhancement Study

The objectives of this study are described in [2].

5 Identified scenarios

Relevant scenarios and antenna configurations for the issues from real-life MIMO deployments include:

- Geographically separated antennas
- Power-imbalanced antenna ports
- Cross-polarized antenna deployments

For CSI feedback enhancements, the following scenarios (A, B, C) were agreed to be studied with high priority, in the following order:

Priority 1: Scenarios A and C

Priority 2: Scenario B

Details of Scenarios A, B and C are given in Annex A.

A. Macro cell: Cross-polarized Macro-sites (2Tx, 4Tx)
  o Closely or widely spaced

B. Outdoor and/or indoor low-power RRHs, with coordination with the macro
  o High power RRH + low power RRHs

C. Outdoor small cell(s) with localized antennas
  o Cross polarized/Co-polarized (mainly 4Tx)
  o Uncorrelated (less correlated)
  o Low mobility

The motivations for this prioritization are that single point transmission should be the focus of this study, and coordination aspects have a lower priority.

The following scenarios are also identified for study with lower priority than scenarios A, B, C:

- Indoor low power node with localized antennas
- Active antennas with vertical beamforming

- Feedback for partial reciprocity
- Homogeneous macro network with 8 cross-polarized antennas (closely or widely-spaced)
- Indoor and/or outdoor low power RRHs without coordination with the macro but with coordination between the low-power RRHs.

6 Issues from Real-Life MIMO Deployments

The following issues are identified as high-priority:

- Time misalignment / antenna calibration
- Downlink control signalling enhancement (including UE-specific RS-based)
- Feedback and related enhancements, including:
  - Interference measurement enhancement
  - Rank reporting
  - CSI accuracy (especially for MU-MIMO) for the high-priority scenarios and antenna configurations.

6.1 Time misalignment / antenna calibration

The performance impact of time misalignment and calibration error has been studied with the summary as follows,

- Time misalignment and calibration error handling is implementation dependent
- Time misalignment and calibration error has less system performance impact for SU-MIMO than for MU-MIMO
- Time misalignment and calibration error does not have significant system performance impact at least for co-located antennas, especially for SU-MIMO
- Sub-band PMI/CQI feedback is more beneficial in the presence of TAE than without TAE
- Any further evaluations on feedback enhancement should take TAE into account – discuss further how/when to model TAE.

6.2 Downlink Control Signalling Enhancements

Downlink control signalling enhancements are discussed in Section 8.

6.3 Feedback Enhancements

6.3.1 Rank Reporting

The accuracy of UE rank reporting was considered in the scenario of geographically separated antennas in a cell, where the received power from different CRS-ports of the cell has a large imbalance. This may for example arise when antenna ports are comprised of interleaved antennas, as shown in Figure 6.3.1-1 [4]. Scenario B (see Section 5) is considered to provide appropriate assumptions for evaluating such deployments.

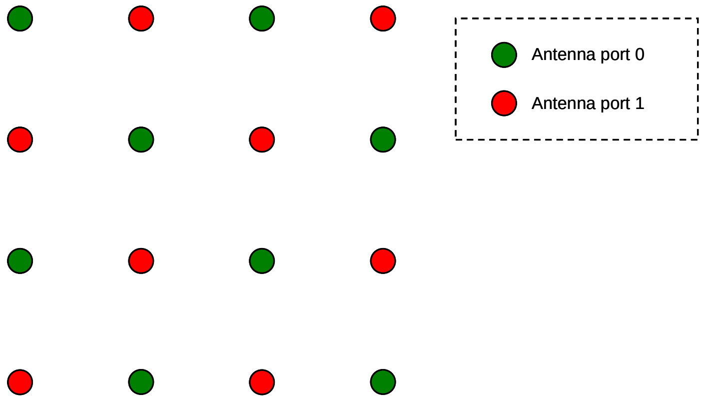

Figure 6.3.1-1: Geographically separated antenna deployment with interleaved antenna ports

In such a deployment, when a UE is close to one antenna the signal strength from the corresponding antenna port is very good, while the other port is much weaker. In between the antenna locations, a good spatial multiplexing gain should be achieved, while close to an antenna the performance should be close to that of single antenna transmission. Overall, the system performance should in theory be significantly improved compared to a SIMO deployment with the same number of antennas.

However, in some measurements it was observed that the throughput became very low close to the antennas while UEs with apparently SINR-based rank estimation still reported RI=2. The rank estimation algorithm of some UEs apparently has problems handling a large power difference between two antenna ports. On the other hand, other UEs were found to have no problems in such scenarios [5].

It is noted that UE implementations should not assume geographical co-location for different antenna ports of a given cell, or in general dependence among antenna ports. The Layer 1 specifications assume that there is flexibility with respect to mapping different antenna ports of a cell to different geographically separated antennas. In particular, geographical co-location may not be assumed for, e.g., antenna ports transmitting cell-specific reference signals (CRS), UE-specific reference signals (DM-RS), and CSI reference signals (CSI-RS). Precoding relies on the independence of different antenna ports, over possibly geographically separated antennas, with the mapping from antenna ports to antennas being transparent to the UE. It is concluded that any problems with this issue should be handled by the development of appropriate performance requirements [6].

6.3.2 Interference Measurement

Interference measurement enhancements for CoMP are handled in the Work Item on Coordinated Multi-Point Operation for LTE [3].

6.3.3 CSI Accuracy

CSI Accuracy enhancements are discussed in Section 7.

7 CSI Feedback Enhancements

The performance of any feedback scheme is the same in CoMP scenario 3 and CoMP scenario 4 assuming Rel-11 allows the necessary specification support. Therefore, it is not needed to run separate simulations for scenarios 3 and 4 for feedback performance evaluation. Simulation assumptions for the evaluation of potential enhancements to CSI feedback are given in Annex A.1.

The main enhancements considered are:

- Enhanced PMI feedback codebook for 4-tx, including cross-polarised antennas, possibly two-stage $W_1.W_2$ structure adopted for the 8-tx codebook in Rel-10, and/or finer codeword granularity in the codebook, and/or capturing the amplitude offset between polarisations.
- Finer frequency-domain sub-band granularity for CSI feedback, for example in conjunction with a new CSI feedback mode including sub-band CQI and sub-band PMI.
- CQI or CQI related feedback specifically for MU-MIMO
- Rank-restriction or PMI selection
- PMI that causes least interference to the reporting UE

With various of the above enhancements, alone or in combination, the results are summarized below.

7.1 Evaluation Results

Different schemes have been simulated. The baseline results are based on Rel-10 specifications. The proposed enhancement schemes being simulated used different quantization rate. Different feedback overheads are assumed. Some enhancement schemes used idealized technique, such as SVD. Some simulation results used idealized assumptions, such as ideal channel estimation, feedbacks, and receivers. Some results are simulated with all UEs outdoors.

Evaluation results were provided by 14 companies [9]

Table 7-1: Scenario A, FDD, Full Buffer

		Relative gain over R10			
		Average	Maximum	Minimum	STD
4 Tx (XX closely-spaced)	**Average Cell SE**	11.8%	23.9%	2.6%	6.4%
	50% ile user SE	13.5%	23.5%	1.8%	7.7%
	5% ile user SE	9.6%	20.6%	-1.3%	0.8%
4 Tx (XX widely-spaced)	**Average Cell SE**	16.1%	31.0%	6.9%	9.8%
	50% ile user SE	13.5%	24.4%	6.2%	9.7%
	5% ile user SE	4.0%	12.7%	-1.9%	6.0%
4 Tx (|||| closely-spaced)	**Average Cell SE**	13.3%	17.5%	3.5%	6.6%
	50% ile user SE	16.2%	23.5%	4.1%	10.6%
	5% ile user SE	11.7%	20.6%	6.5%	6.4%

* The results closed to Maximum are very few. The maximum results are simulated with all outdoor UEs, which is optional in evaluation and is not typical for scenario A.

Table 7-2: Scenario A, FDD, non-Full Buffer[1]

		Relative gain over R10			
		Average	Maximum	Minimum	STD
4 Tx (XX, closely-spaced)	**Average Cell SE**	2.9%	2.9%	2.9%	N/A
	50% tile user SE	10.6%	10.6%	10.6%	N/A
	5% tile user SE	11.7%	11.7%	11.7%	N/A

* Note that the results are based on one company's results.

Table 7-3: Scenario C1, FDD, Full Buffer

		Relative gain over R10			
		Average	Maximum	Minimum	STD
4 Tx (XX closely-spaced)	**Average Cell SE**	7.2%	11.8%	2.7%	3.3%
	50% ile user SE	8.3%	14.0%	0.6%	5.2%
	5% ile user SE	7.6%	16.7%	-1.3%	7.8%
4 Tx (|||| closely-spaced)	**Average Cell SE**	9.6%	12.8%	3.8%	3.4%

1

	50% ile user SE	10.5%	15.0%	3.6%	6.0%
	5% ile user SE	6.5%	14.3%	-1.7%	6.0%
4 Tx (|||| widely-spaced)	**Average Cell SE**	7.8%	7.8%	7.8%	N/A
	50% ile user SE				
	5% ile user SE	0.0%	0.0%	0.0%	N/A

Table 7-4 Scenario C1, FDD, non-Full Buffer

		Relative gain over R10			
		Average	Maximum	Minimum	STD
4 Tx (XX, cross-polarized)	**Cell SE over R10**	0.9%	0.9%	0.9%	N/A
	50% tile user SE	6.4%	6.4%	6.4%	N/A
	5% tile user SE	3.1%	3.1%	3.1%	N/A

* Note that the results are based on one company's results

Table 7-5: Scenario C2, FDD, Full Buffer

		Relative gain over R10			
		Average	Maximum	Minimum	STD
4 Tx (XX closely-spaced)	**Average Cell SE**	7.3%	18.7%	-0.1%	5.8%
	50% ile user SE	10.5%	28.4%	0.4%	9.2%
	5% ile user SE	10.9%	21.5%	-1.5%	6.7%
4 Tx (XX widely-spaced)	**Average Cell SE**	2.8%	5.4%	0.3%	3.6%
	50% ile user SE				
	5% ile user SE	16.7%	19.0%	14.4%	3.3%
4 Tx (|||| closely-spaced)	**Average Cell SE**	11.5%	19.0%	5.7%	5.5%
	50% ile user SE	16.2%	19.6%	12.8%	4.8 %
	5% ile user SE	7.5%	11.4%	0.8%	5.0%
4 Tx (|||| widely-spaced)	**Average Cell SE**	6.7%	6.7%	6.7%	N/A
	50% ile user SE				
	5% ile user SE	-0.2%	-0.2%	-0.2%	N/A

*The results closed to Maximum are very few and the results of 4 Tx (|||| widely-spaced) are from one company.

Table 7-6 Scenario C2, FDD non-Full Buffer[2]

		Relative gain over R10			
		Average	Maximum	Minimum	STD
4 Tx (XX, cross-polarized)	**Average Cell SE**	0.5%	0.5%	0.5%	N/A
	50% tile user SE	9.4%	9.4%	9.4%	N/A
	5% tile user SE	4.6%	4.6%	4.6%	N/A

* Note that the results are based on one company's results

Table 7-7: Scenario B, FDD, Full Buffer[3]

		Relative gain over R10			
		Average	Maximum	Minimum	STD
Macro 4 Tx (XX closely-spaced) RRH 2 Tx (X cross-polarized)	**Average Cell SE**	13.0%	13.0%	13.0%	N/A
	50% ile user SE	14.0%	14.0%	14.0%	N/A
	5% ile user SE	17.8%	17.8%	17.8%	N/A
Macro 4 Tx (XX closely-spaced) RRH: 2 Tx (|| vertically-polarized)	**Average Cell SE**	12.1%	12.1%	12.1%	N/A
	50% ile user SE	15.0%	15.0%	15.0%	N/A
	5% ile user SE	19.2%	19.2%	19.2%	N/A

Macro 4 Tx (XX closely-spaced) RRH 4 Tx (XX cross-polarized)	**Average Cell SE**	7.6%	7.6%	7.6%	N/A
	50%ile user SE	10.4%	10.4%	10.4%	N/A
	5% ile user SE	1.2%	1.2%	1.2%	N/A

*Note that the results are based on one company's results for 2 Tx RRH and the other one company's results for 4 Tx RRH

- **Observation**: A large variation in the presented gain due to difference in assumptions, e.g.
  - Variety of schemes from idealistic explicit feedback to realistic implicit feedback
  - CSI feedback overhead (e.g. modes, subband sizes)
  - Modeling of CSI-RS and DMRS based estimation
  - CSI quantization
  - Scheduling schemes
  - Maximal transmission rank.
  - Type of receivers
  - Some results are based on single enhancement scheme and other results are based on multiple enhanced schemes in combination.

Scenario A, and C are high priority scenarios in the evaluation and Scenario B has been investigated with lower priority.. Other aspects were not assigned a high priority during this study and may be considered in the future.

8 Downlink Control Signalling Enhancements

The motivations for introducing an enhanced PDCCH (ePDCCH) were considered [7]. It was noted that an ePDCCH is relevant not only to downlink MIMO enhancement (in particular MU-MIMO), but also to a new carrier type being developed under the Work Item "Carrier Aggregation Enhancements for LTE" [8] and to the Work Item "Coordinated Multi-Point Operation for LTE" [3]. Based on considerations from these three aspects, it is concluded that any new ePDCCH should be:

- able to support increased control channel capacity
- able to support frequency-domain ICIC,
- able to achieve improved spatial reuse of control channel resource
- able to support beamforming and/or diversity
- able to operate on the new carrier type and in MBSFN subframes
- able to coexist on the same carrier as legacy UEs

Additional desirable characteristics include the ability to be scheduled frequency-selectively, and the ability to mitigate inter-cell interference.

Simulation assumptions for the evaluation of an ePDCCH are given in Annex A.2.

9 Specification Impacts

For rank reporting, the potential specification impacts identified relate to the UE performance requirements.

For CSI feedback enhancements, the potential specification impacts for the considered techniques include:

- A new PMI feedback codebook for 4-tx

- PUSCH feedback mode additions

- PUCCH feedback mode schemes and formats.

- Signalling to configure CSI feedback, including codebooks, rank restriction, etc

- Feedback of multiple PMIs/CQIs/CSIs, which include multiple PMIs/single CQI, multiple PMIs/multiple CQIs, single PMIs/multiple CQIs.

- New additional CQI definition and new additional methodology to specify the UE performance requirements.

- New additional PMI definition and new additional methodology to specify the UE performance requirements.

For downlink control channel enhancements, the potential specification impacts include the definition of a new physical channel with corresponding coding, search space design, reference signals and physical resource mapping. New demodulation performance requirements would also be required.

10 Conclusions

According to the discussions and performance evaluation results captured in the previous sections, the following conclusions are drawn:

- Identified real-life issues with UE rank reporting in non-colocated antenna deployments should be handled by the development of appropriate performance requirements.
- According to the summary of all simulation results, CSI feedback enhancements for 4 transmit antennas may offer some performance benefits for antenna configurations, such as cross-polarized antennas, both closely- and widely-spaced. Potential CSI feedback enhancements proposed by at least one company are as follows
    - 4-tx PMI feedback codebook enhancements
    - a new CSI feedback mode including sub-band CQI and sub-band PMI
    - finer spatial-domain and frequency-domain granularity
    - signalling to support codebook enhancement .
    - Additional CQI/PMI feedbacks to support MU-MIMO
    - Combinations of above
- The need of enhancements for downlink control signalling - Capacity, Frequency domain ICIC, Beamforming gain and Spatial reuse of control channels have been the most supported motivations for the decision to introduce an enhanced physical downlink control channel in Rel. 11
  - MIMO enhancement provides further motivation for introducing a new physical downlink control channel, which is also relevant for carrier aggregation enhancement and CoMP.

In view of these observations, it is recommended at least to specify appropriate performance requirements to ensure the accuracy of UE rank reporting in non-collocated antenna deployments and to continue with specifying a new downlink physical control channel. An agreement on whether to specify CSI feedback enhancements has not been reached.

Annex A: Simulation assumptions

A.1: Simulation assumptions for CSI Feedback Enhancements

The system simulation parameters for the evaluations of downlink MIMO CSI feedback enhancements are as specified in TR 36.814, modified as per Annex A of TR36.819, modified as per Table A1.

Table A1: System simulation parameters for DL MIMO CSI feedback evaluations

Parameter	Assumption
Performance metrics	Cell average throughput 5%ile and 50%ile of the user throughput CDF. For scenarios C1 and C2, performance metrics are only collected from the UEs associated with a small cell
Deployment scenarios	A. Homogeneous macro network (2Tx, 4Tx) - Reuse the macro part of the baseline simulation case for scenario 4 in TR36.819, unless otherwise stated in this table B. Network with low power Tx points for both outdoor and indoor within the macrocell coverage - Reuse the assumptions from scenario 3/4 in the CoMP SI with configuration 4b of TR36.814, unless otherwise stated in this table - CoMP is allowed C. Outdoor low-power Tx points - reuse the assumptions from scenario 3/4 in the CoMP SI with configuration 4b of TR36.814, unless otherwise stated in this table C1: with macro cell on the same carrier frequency - no coordination between the low-power Tx points, nor with the macro C2: with macro cell on an adjacent carrier frequency - no coordination between the Tx points - the macro cell has to be taken into account in the cell selection mechanisms
Antenna configurations	For macro eNB, in priority order for each number of antennas: • 2 Tx antennas 1. 1 column, cross-polarized: X

	• 4 Tx antennas 1. 2 columns, cross-polarized on each column, closely-spaced: X X 2. 2 columns, cross-polarized on each column, widely-spaced: X X • 8 Tx antennas 1. 4 columns, cross-polarized on each column, closely spaced: X X X X 8 Tx has lower priority than 2 and 4 Tx For low power node • 1 Tx antenna: vertically-polarized • 2 Tx antennas: 1. cross-polarized: X 2. 0.5 λ- closely spaced vertically-polarized: | | 3. 4 λ- widely spaced vertically-polarized: | | • 4 Tx antennas: 1. 0.5 λ-spaced cross-polarized: X X 2. 4 λ-spaced cross-polarized: X X 3. 0.5 λ-spaced vertically-polarized: | | | | 4. 4 λ-spaced vertically-polarized: | | | | Array orientation needs to be defined (e.g., random for 4 Tx) The 1Tx antenna case does not apply for scenario C 4Tx has higher priority than 1 and 2 Tx For UE: • 2Rx cross-polarized: X 2Tx cross-polarized • 2Rx cross-polarized: X 1Tx vertically-polarized
Feedback schemes	Baseline: Release 10 codebooks and feedback formats. Single-cell CSI feedback enhancements should be described, including details of overhead and delay assumed.
Channel model	For scenario A: Baseline: use the macro part of the baseline channel of scenario 4 in the CoMP SI with indoor-outdoor modeling Optional: same as the baseline except that 100% of the UEs are dropped outdoors For scenario B: Baseline: use the baseline channel of scenario 3/4, with the following alternatives for the UE indoor dropping: Mandatory]: all UEs are dropped outdoors

	Optional]: UEs dropped in the low power node areas have a 25% probability of being indoors; the remaining UEs are dropped over the macro cell geographical area with a 80% probability of being indoors [Optional]: all UEs are dropped with a 80% probability of being indoors For scenario C: Baseline: use the baseline channel of scenario 3/4, with the following alternatives for the UE indoor dropping: [Mandatory]: all UEs are dropped outdoors [Optional]: UEs dropped in the low power node areas have a 25% probability of being indoors; the remaining UEs are dropped over the macro cell geographical area with a 80% probability of being indoors [Optional]: all UEs are dropped with a 80% probability of being indoors
Traffic models	Full buffer Non full buffer
Impairments modeling	Optional for feedback investigations: Timing misalignment between antenna • the modeling needs to be described when presenting results Optional for feedback investigations: Modelling of antenna Tx -Rx pair calibration error (for TDD) • the modeling needs to be described when presenting results

A.2: Simulation assumptions for Downlink Control Channel Enhancements

The assumptions for evaluations of downlink control channel enhancements are given in Table A2. The evaluation metric is the BLER for different CCE aggregation levels.

Table A2: System simulation parameters for DL control channel enhancement evaluations

Parameter	Assumption
DCI Formats	0/1A, 2C
System BW	10 MHz
UE speed	3 km/h, 30 km/h, 120 km/h 350 km/h can also be considered
Antenna Configurations	2x2, 4x2, 8x2 (TDD only) With cross-polarization

Carrier Frequency	2.0 GHz
Channel Models	For correlated channel evaluations: SCM-B; SCME (with Urban macro small angular spread scenario with 1,2 or 4 cross poles for 2,4 and 8 Tx respectively, 0.5λ spaced; at the UE, cross-pole antenna). For uncorrelated channel evaluations: ETU; EPA optional.
Channel estimation	Realistic. Based on Rel-10 DM-RS for beamformed control channel transmissions.
Modulation	QPSK
Modelling of interference variations per PRB per subframe	AWGN initially. May also consider interference statistics generated from system level simulations.
CSI feedback for beamformed transmissions	PUSCH mode 3-1, wideband PMI Based on CSI-RS CSI feedback delay: 10 ms; other values such as 5 ms and 20 ms can also be considered. Aperiodic CSI feedback is assumed to be available in every subframe UE speed variability can serve to indicate impact of non-ideal CSI feedback delays UE feeds back CSI assuming the transmission rank is 1 (SU). The case of rank assumptions for CSI feedback can also be considered CSI sub-band granularity (values specified at 10 MHz) Assume error free feedback, using Rel-10 codebooks

Annex B: Change history

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
2011-05	RAN1_65	-	-	-	Initial Draft in R1-111982		0.1.0
2011-09	RAN1_66bis	-	-	-	Inclusion of agreements from RAN1#66 and email discussion 66-07 in R1-113332	0.1.0	0.1.1
2011-09	RAN1_66bis	-	-	-	Approved by RAN1 in R1-113587	0.1.1	1.0.0
2011-11	RAN1_67	-	-	-	Inclusion of text in all main sections - to be presented to RAN#54 for information (R1-114473)	1.0.0	1.1.0
2011-12	RAN_54	RP-111677	-	-	Approved by RAN_54 as version 11.0.0 – under change control	1.1.0	11.0.0