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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:

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x the first digit:

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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

The objective of this study is to evaluate the use of measurements for positioning, which are currently specified for UE and eNodeB for other purposes but are not currently included in LPP and LPPa, for an RF pattern matching positioning technology in LTE.
The RFPM performance with these measurements will be compared to the RFPM performance based on the measurements currently specified for the E-CID location method.

The implementation could be an E-SMLC based eNodeB-assisted location service using existing E-UTRAN measurements which are provided to the E-SMLC via the LPPa positioning protocol and UE-assisted location service using existing UE measurements (RSRP, RSRQ and UE Rx-Tx time difference only) which are provided to the E-SMLC via LPP positioning protocol.

The present document is intended to complement already 3GPP standardized location methods and existing 3GPP location work items.

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 TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation".

[3] 3GPP TR 36.942: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) system scenarios".

[4] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements".

[5] R4-115510: "Way forward on RFPM simulation approaches", Huawei, HiSilicon, Polaris Wireless, Ericsson.

[6] "Adaptive Enhanced Cell-ID Fingerprinting Localization by Clustering of Precise Position Measurements", Wigren, T., Ericsson AB, Stockholm, IEEE Transactions on Vehicular Technology, Volume 56, Issue 5, pages 3199-3209, Sept 2007.

[7] R4-093039:"Proposed system simulation assumptions for OTDOA positioning", Ericsson, ST-Ericsson.

[8] 3GPP TS 36.133: "Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management"."

[9] 3GPP TS 36.305: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Stage 2 functional specification of User Equipment (UE) positioning in E-UTRAN".

[10] 3GPP TS 36.455: "Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Positioning Protocol A (LPPa)".

[11] 3GPP TS 36.355: "Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Positioning Protocol (LPP)".

[12] "3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements".

[13] 3GPP TR 36.814: "Evolved Universal Terrestrial Radio Access (E-UTRA); Further advancements for E-UTRA physical layer aspects".

[14] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification".

[15] R4-130636: "RFPM simulation results".[16] R4-132371: "Initial Inter-RAT RFPM simulation results".

[17] R4-133575: "Simulation results of RFPM with UMTS".

[18] R4-133620: "Further RFPM Simulation Results with Inter-RAT Measurements".

[19] R4-132670: "Further RFPM Simulation Results".

3 Definitions and abbreviations

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].

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].

CRS Cell specific Reference Signal
E-CID Enhanced Cell Identification
E-SMLC Enhanced Serving Mobile Location Centre
LPP LTE Positioning Protocol
LPPa LTE Positioning Protocol A
OTDOA Observed Time Difference of Arrival
PRS Positioning Reference Signal
RFPM Radio Frequency Pattern Matching
RSRP Referenced Signal Received Power
RSRQ Reference Signal Received Quality
SLP SUPL Location Platform
SUPL Secure User Plane Location

4 General description of RF Pattern Matching (RFPM)

Radio Frequency Pattern Matching (RFPM) sometimes referred to as RF fingerprinting, is a general class of positioning techniques by which a set of RF measurements, made either by the UE or the eNB, is compared against a reference set of values in order to estimate the UE location, where the reference set of values may be based on predicted and/or collected measurements. Typical types of RF measurements include signal strength measurements and timing measurements. In LTE, the signal strength measurements would correspond to Referenced Signal Received Power (RSRP) while the timing measurements may correspond to the UE Rx-Tx measurement. By increasing the number of measurements of a good quality from different sectors the location accuracy will improve. Different methods exist for location estimation for RPFM and for obtaining reference measurements; these methods are typically implementation specific.

5 LTE architecture for RFPM

Implementation of RFPM may rely on the fundamental location architecture as described in 3GPP TS 36.305 [9], where a positioning server is E-SMLC in the control plane or SLP in the user plane, and positioning protocols LPP and LPPa would facilitate gathering the needed information to perform a location estimate.

6 Simulation methodology

6.1 Overview

The goal of the study is to evaluate the RFPM positioning performance. This evaluation includes a baseline performance characterisation where only existing measurements available in the E-CID Positioning Method are used as well as enhancements to RFPM where low interference conditions and inter-RAT measurements are included.

In order to do the performance characterization of each scenario RFPM is simulated using system level simulations (optionally link level simulations). The general flow is outlined in the following steps:

(1) Generate RF maps for each sector in the network in accordance with parameters specified clause 6.5.1;

(2) Randomly place UEs in the network;

(3) Compute the corresponding interference based on the given scenario for each UE;

(4) For each UE simulate the UE Rx-Tx measurement and the RSRP measurement;

   a. In scenarios with inter-RAT measurements, simulate also measurements corresponding to other RATs.

(5) Using RFPM compute the position estimate;

(6) For each UE, calculate the error comparing the estimated position obtained in Step 5 to the actual position.

6.2 Network topology

The network topology is a macro network deployment as in 3GPP TR 36.814 [13].

6.3 Location methods to be simulated

A baseline performance for RFPM is established by simulating the performance using just those measurements available in LPP / LPPa for E-CID . Specifically, these measurements are intra-frequency RSRP, and UE Rx-Tx time difference.

The measurements are as specified in 3GPP TS 36.214 [12].

Two additional scenarios will be evaluated to assess the performance improvement offered to RFPM:

- Intra-frequency RSRP and UE Rx-Tx time difference measurements performed in subframes with reduced interference (e.g. without any data traffic in interfering cells)

- Intra-frequency RSRP, UE Rx-Tx time difference and on inter-RAT measurement, with an emphasis placed on GSM as the additional RAT.

The RFPM simulation will use the maximum likelihood method for deriving the location estimate.
The position estimation approach for RFPM is as in Annex A.

6.4 Error models

6.4.1 RFPM error model

RFPM works by comparing a set of measurements against a model of the RF environment. As such, it is important to characterize the error that exists both in the RFPM model but also in the UE measurements.

Two types of errors are modelled in the RFPM simulation studies:

- prediction and reference data error (includes e.g. prediction error, model fitting error, reference data error, etc.)
- real-time measurement error (includes e.g. measurement accuracy requirement 3GPP TS 36.133 [8], terminal carrier error, body impact, etc.)

In the former case the error may have several sources such as prediction error (i.e. the fidelity in which one can accurately predict the RF environment) and reference data error (i.e. if field measurements are used to improve the prediction, their intrinsic measurement error must also be included). Figure 6.4.1-1 highlights how these two error mechanisms work with what is the actual RF environment in a simulation.

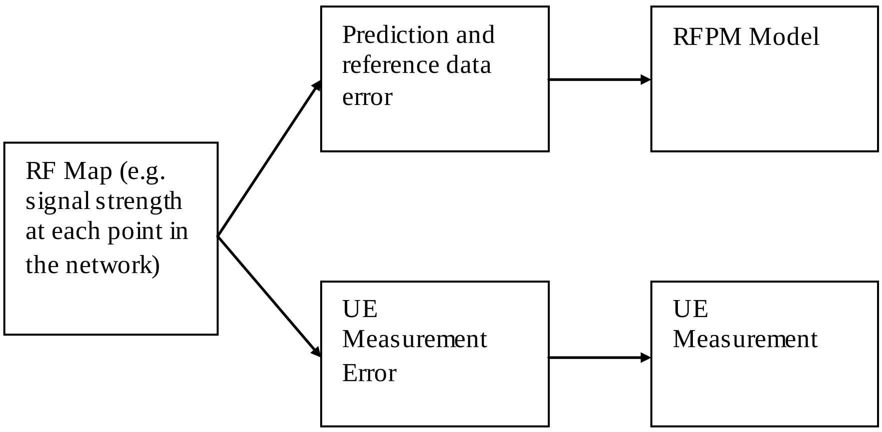


Figure 6.4.1-1: RFPM error models

For the purposes of simulation a RF map is generated for each cell in accordance with the parameters outlined in clause 6.5.1. The RFPM model error is assumed to be normally distributed and has two components as it may be the case that some portion of the time we select the wrong RF model parameters for the environment:

- e1: RMS = 9 dB (for 90% of randomly select UEs)
- e2: RMS = 13 dB (for 10% of randomly selected UEs)

For the simulated UE measurements the error must account for not only the intrinsic measurement error from the UE as specified in 3GPP TS 36.133 [8], but also the possibility that the UE may be oriented in different ways with respect to the user yielding head/body effects on the actual measurements in relation to the RF environment. It is also true that the UE error performance will be better in low interference conditions than in high interference conditions.
Hence, two scenarios are captured, both assuming normally distributed errors:

- RMS = 6.5 dB (normal subframes at full system load)
- RMS = 5.7 dB (subframes with reduced interference)

6.5 Simulation assumptions

6.5.1 System-level simulation parameters

The system-level simulation parameters are summarized in Table 6.5.1-1, most of which are based on [7].

Table 6.5.1-1: Summary of system-level simulation parameters

<table>
<tr><th colspan="2">Parameter</th><th>Value</th></tr>
<tr><td colspan="2">Cell layout</td><td>Hexagonal Grid, wrap around</td></tr>
<tr><td colspan="2">Number of sites</td><td>19 sites, with 3-sectored antennas at each site</td></tr>
<tr><td colspan="2">Inter-Site distance</td><td>500 m, 1732 m</td></tr>
<tr><td colspan="2">Antenna gain</td><td>15 dBi (3-sector antenna as defined in 3GPP TR 36.942 [3])</td></tr>
<tr><td colspan="2">Distance-dependent pathloss</td><td>$L=128.1+37.6\log_{10}(R)$ (R in km)</td></tr>
<tr><td colspan="2">Carrier frequency</td><td>2 GHz (E-UTRAN FDD band 1)</td></tr>
<tr><td colspan="2">Penetration loss and UE speed</td><td>Indoor: 20 dB, 3 km/h for 500m and 1732m (Case 1 and Case 3)
Outdoor: 10 dB, 30 km/h for 500m (Case 2)</td></tr>
<tr><td colspan="2">Minimum distance between UE and BS</td><td>35 m</td></tr>
<tr><td colspan="2">Carrier bandwidth</td><td>10 MHz, optionally 1.4 MHz</td></tr>
<tr><td colspan="2">eNode B power</td><td>46 dBm for 10 MHz</td></tr>
<tr><td colspan="2">UE noise figure</td><td>9 dB</td></tr>
<tr><td colspan="2">Lognormal shadowing standard deviation</td><td>8 dB</td></tr>
<tr><td rowspan="2">Shadowing correlation</td><td>Between sites</td><td>0.5</td></tr>
<tr><td>Between sectors</td><td>1</td></tr>
<tr><td colspan="2">Correlation distance of shadowing</td><td>50 m</td></tr>
<tr><td colspan="2">Channel model</td><td>ETU
Optional: Urban A, Urban B and Bad Urban profiles of T1P1</td></tr>
<tr><td colspan="2">Network synchronization</td><td>Synchronous (baseline), Asynchronous</td></tr>
<tr><td colspan="2">Cyclic prefix</td><td>Normal</td></tr>
<tr><td colspan="2">Number of eNodeB transmit antennas</td><td>2</td></tr>
<tr><td colspan="2">Number of CRS antenna ports</td><td>1</td></tr>
<tr><td colspan="2">Number of PRS antenna ports</td><td>1</td></tr>
<tr><td colspan="2">PRS and positioning subframe configuration</td><td>As defined in TS 36.211 [2]. No data transmitted during these positioning subframes</td></tr>
<tr><td colspan="2">Number of UE transmit antennas</td><td>1</td></tr>
<tr><td colspan="2">Number of UE receive antennas</td><td>2</td></tr>
<tr><td colspan="2">Number of eNodeB receive antennas</td><td>2</td></tr>
<tr><td colspan="2">Traffic load in non-positioning subframes</td><td>Full load</td></tr>
<tr><td colspan="2">Candidate cells</td><td>Cells whose CRS SINR at the UE is above or equal to -6 dB.</td></tr>
<tr><td colspan="2">UE Rx-Tx</td><td>Normally distributed, RMS Error of 6Ts</td></tr>
<tr><td colspan="2">RSRP</td><td>Normally Distributed with RMS Error:
• 6.5 dB in full load subframes
• 5.7 dB in reduced interference subframes</td></tr>
<tr><td rowspan="5">GSM IRAT</td><td>Cell Layout</td><td>Co-located with LTE Cells and Frequency Reuse of 12</td></tr>
<tr><td>Detection Threshold</td><td>-104 dBm and 9 dB SNR</td></tr>
<tr><td>Tx Power</td><td>MSR BS with Total Power = 46 dBm
LTE Tx Power = 43 dBm
GSM Tx Power = 43 dBm</td></tr>
<tr><td>Prediction and data error models</td><td>Same as LTE</td></tr>
<tr><td>Measurement Error</td><td>Normally distributed with RMS Error of 5.7 dB</td></tr>
<tr><td rowspan="5">UMTS IRAT</td><td>Cell Layout</td><td>Co-located with LTE Cells</td></tr>
<tr><td>Detection Threshold</td><td>CPICH Ec/Io>=-20 dB and SCH_EC/Io >= -17 dB for at least one channel tap and SCH_Ec/Ior is equally divided between primary synchronisation channel and secondary synchronisation channel</td></tr>
<tr><td>Tx Power</td><td>MSR BS with Total Power = 46 dBm
LTE Tx Power = 43 dBm
UMTS Tx Power = 43 dBm</td></tr>
<tr><td>Prediction and data error models</td><td>Same as LTE</td></tr>
<tr><td>Measurement Error</td><td>Normally distributed with RMS Error of 5.7 dB</td></tr>
</table>

6.5.2 Link-level simulation parameters

The parameters that are common for system- and link-level simulations are as in Table 6.5.1-1. Measurement-specific parameters are as specified further below. Link level simulations are optional and how specifically to model the scenarios under consideration are FFS.

Editor's note: The simulation parameters in this clause are working assumptions, may be revisited depending on the results.

6.5.2.1 Referenced Signal Received Power (RSRP)

The RSRP link-level simulation parameters are summarized in Table 6.5.2.1-1.

Table 6.5.2.1-1: Link-level simulation parameters for RSRP

Parameter	Value
Measurement bandwidth	Same as Table 6.5.1-1
L1 measurement period	200 ms
Measurement sampling rate	5 samples per L1 period
L3 filtering	Disabled
Number of Tx antennas	1
Number of Rx antennas	2 equal gain uncorrelated antennas
Propagation conditions	Same as Table 6.5.1-1
Candidate cells	Cells whose CRS SINR at the UE is above or equal to [-6] dB.

6.5.2.2 UE Rx-Tx

The UE Rx-Tx link-level simulation parameters are summarized in Table 6.5.2.2.-1.

Table 6.5.2.2-1: Link-level simulation parameters for UE Rx-Tx

Parameter	Value
Measurement bandwidth	Same as Table 6.5.1-1
L1 measurement period	200 ms
Measurement sampling rate	5 samples per L1 period
L3 filtering	Disabled
Number of Tx antennas	1
Number of Rx antennas	2 equal gain uncorrelated antennas
Propagation conditions	Same as Table 6.5.1-1
Candidate cells	Cells whose CRS SINR at the UE is above or equal to [TBD] dB

6.5.3 Propagation models

See Table 6.5.1-1 in clause 6.5.1 for parameters of the RF propagation models.

7 Simulation results and observations

Simulation results are presented in this clause for the following scenarios:

- **Scenario 1:** (baseline): based on LTE measurements (RSRP and UE Rx-Tx) in full-load conditions,
- **Scenario 2:** based on LTE measurements (RSRP and UE Rx-Tx) in reduced-interference subframes,
- **Scenario 3:** based on LTE measurements (RSRP and UE Rx-Tx) in full-load conditions and GSM RSSI measurements,
- **Scenario 4:** based on LTE measurements (RSRP and UE Rx-Tx) in reduced-interference subframes and GSM RSSI measurements,
- **Scenario 5:** based on LTE measurements (RSRP and UE Rx-Tx) in full-load conditions and UMTS CPICH RSCP measurements,
- **Scenario 6:** based on LTE measurements (RSRP and UE Rx-Tx) in reduced interference subframes and UMTS CPICH RSCP measurements,
- **Scenario 7:** based on LTE measurements (RSRP and UE Rx-Tx) in reduced interference subframes, UMTS CPICH RSCP measurements and GSM RSSI measurements,
- **Scenario 8**: based on LTE measurements (RSRP and UE Rx-Tx) in full-load conditions and UMTS CPICH RSCP measurements during IPDL,
- **Scenario 9:** based on LTE measurements (RSRP and UE Rx-Tx) in reduced interference subframes and UMTS CPICH RSCP measurements during IPDL and,
- **Scenario 10:** based on LTE measurements (RSRP and UE Rx-Tx) in reduced interference subframes, UMTS CPICH RSCP measurements during IPDL, and GSM RSSI measurements.

Several observations can be made based on the results of the simulation study:

- **Observation 1:** When LTE measurements are made in low-interference subframes the performance improves significantly. In the urban 10 MHz case the 67th percentile error is reduced 30% while in the suburban 10 MHz case the 67th percentile error is reduced 47%.
- **Observation 2:** Including GSM RSSI measurements adds some improvement to the RFPM performance. In the urban 10 MHz case the 67th percentile error is reduced 11% while in the suburban 10 MHz case the 67th percentile error is reduced 23%.
- **Observation 3:** Combining both the GSM RSSI measurement enhancement and the LTE measurements in low-interference subframe enhancement in an urban 10 MHz condition reduces the 67th percentile error by 37% while it reduces the suburban 10 MHz 67th percentile error by 54%.
- **Observation 4:** Adding UMTS inter-RAT measurements shows improvement albeit not quite to the extent of the GSM inter-RAT scenario. When UMTS intra-RAT measurements are made during IPDL periods the results are improved over the full-load LTE with GSM inter-RAT scenario (Scenario 3).
- **Observation 5:** Combining UMTS inter-RAT and GSM inter-RAT along with LTE measurements in low-interference subframes yields the greatest performance impact decreasing the 67th percentile error 44% and 47% for the cases when the UMTS inter-RAT measurements aren't made and are made during IPDL respectively.
- **Observation 6:** The grid spacing influences the performance of RFPM, as evidenced by a 2%-6% increase in the baseline 67th percentile error when moving from 10 meter bin spacing to 50 meter bin spacing when comparing same company results. However, the relative performance improvements offered when LTE measurements are made in reduced-interference subframes or when GSM RSSI or UMTS RSCP measurements are included hold.

7.1 Urban 10 MHz bandwidth case

Table 7.1-1 provides company averaged simulation results for the baseline (scenario 1), reduced interference subframe (scenario 2), GSM inter-RAT (scenario 3), and combined reduced interference subframe and GSM inter-RAT (scenario 4) for 10 MHz bandwidth in an urban environment. The results establish the improvements offered by both the studied enhancements, which, when combined reduce the overall 67th percentile error by 36%.

Table 7.1-1: Company average simulation results

Scenario	Urban (500 m ISD) 10 MHz	
	67th Percentile (meters)	95th Percentile (meters)
Baseline (Scenario 1)	163	337
Reduced Interference Subframe (Scenario 2)	113	275
GSM Inter-RAT (Scenario 3)	145	333
Reduced Interference Subframe and GSM Inter-RAT (Scenario 4)	103	261
UMTS Inter-RAT (Scenario 5)	148	337
Reduced Interference Subframe and UMTS Inter-RAT (Scenario 6)	116	264
Reduced Interference Subframe and both GSM and UMTS inter-RAT (Scenario 7)	91	241
UMTS Inter-RAT with IPDL (Scenario 8)	115	288
Reduced Interference Subframe and UMTS Inter-RAT with IPDL (Scenario 9)	107	275
Reduced Interference Subframe, GSM Inter-RAT and UMTS Inter-RAT with IPDL Scenario 10	85	232
NOTE: Scenarios 1 and 2 based on results from 4 companies. Scenarios 3 and 4 based on results from 3 companies. Scenarios 5,6,8 and 9 based on results from 2 companies. Scenarios 7 and 10 based on results from a single company.		

In addition to the company averaged results, more complete individual company results are plotted in Figures 7.1-1 to7.1-4.

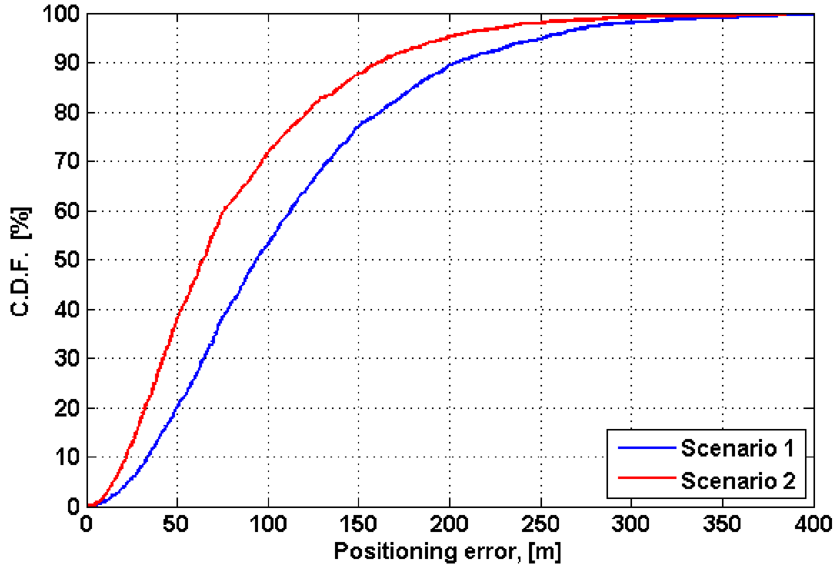


Figure 7.1-1: Ericsson, ST-Ericsson simulation results from R4-130636 [15]

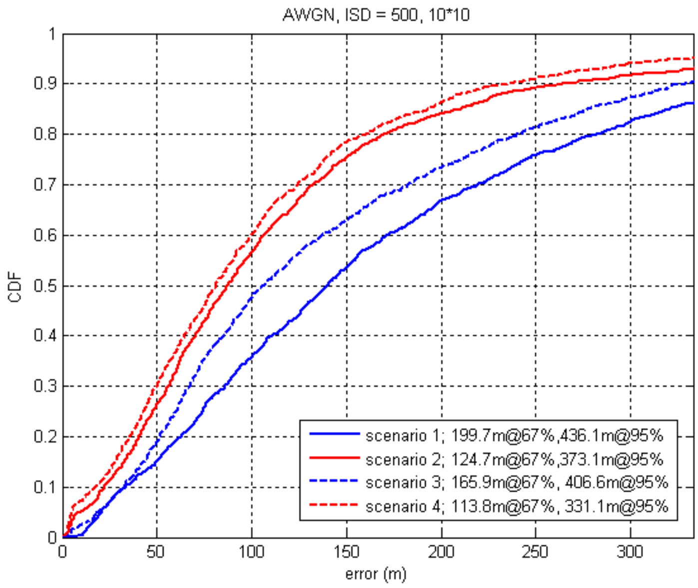


Figure 7.1-2: Huawei simulation results from R4-130636 [15]

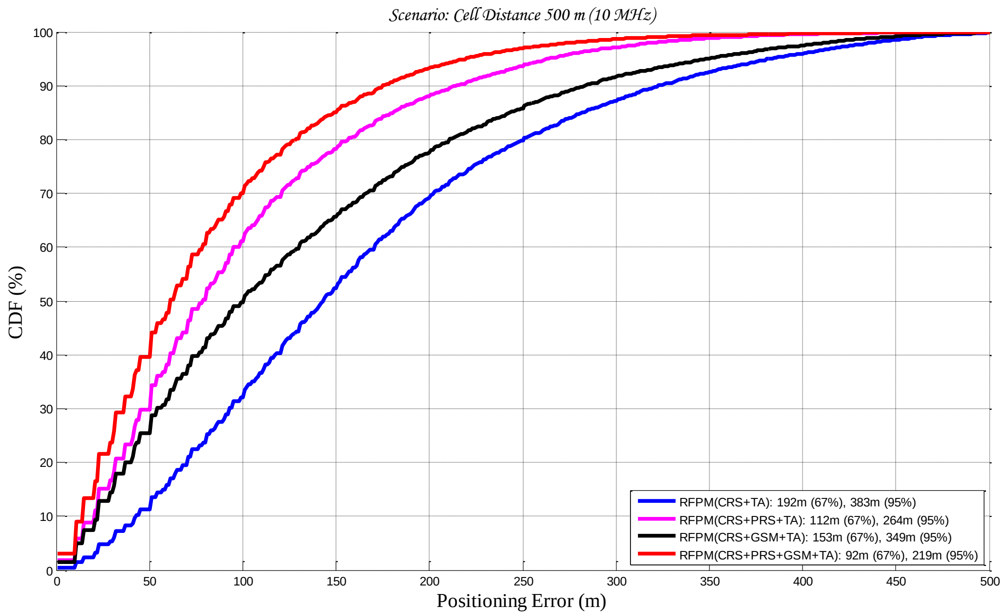


Figure 7.1-3: Alcatel-Lucent simulation results with GSM inter-RAT from R4-132371 [16]

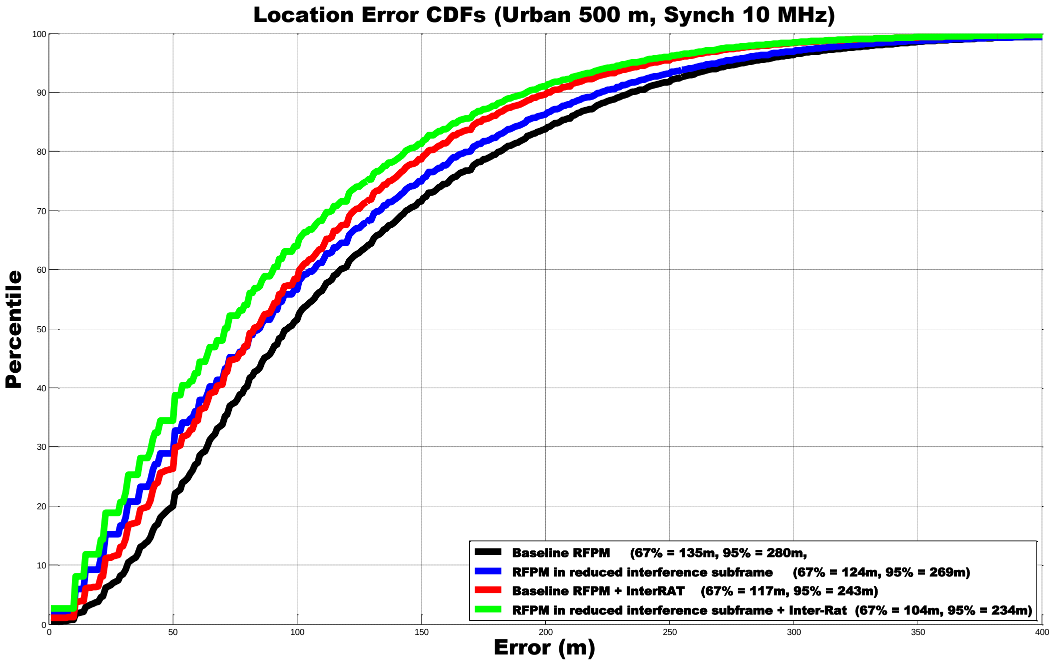
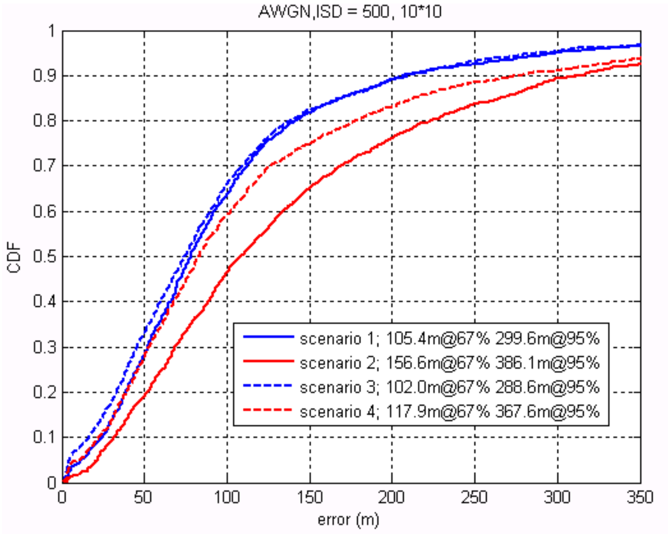


Figure 7.1-4: Polaris Wireless simulation results with GSM inter-RAT from R4-132670 [19]



NOTE: Scenarios 1,2,3, and 4 in this figure correspond to scenarios 5,6,8 and 9 respectively.

Figure 7.1-5: Huawei results with UMTS inter-RAT from R4-133575 [17]

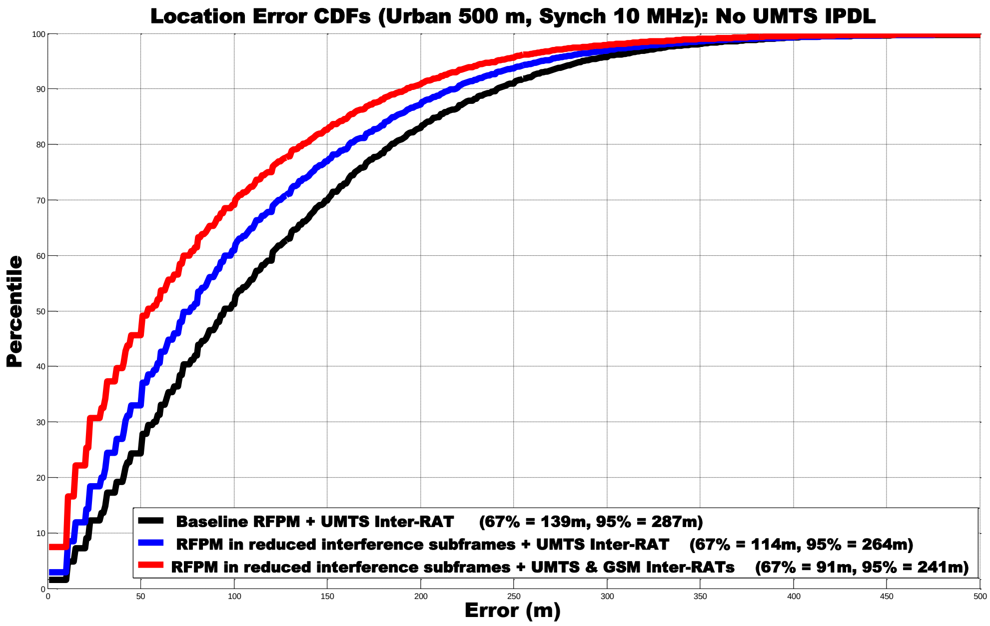


Figure 7.1-6: Polaris Wireless Simulation Results for UMTS inter-RAT without IPDL from R4-133620 [18]

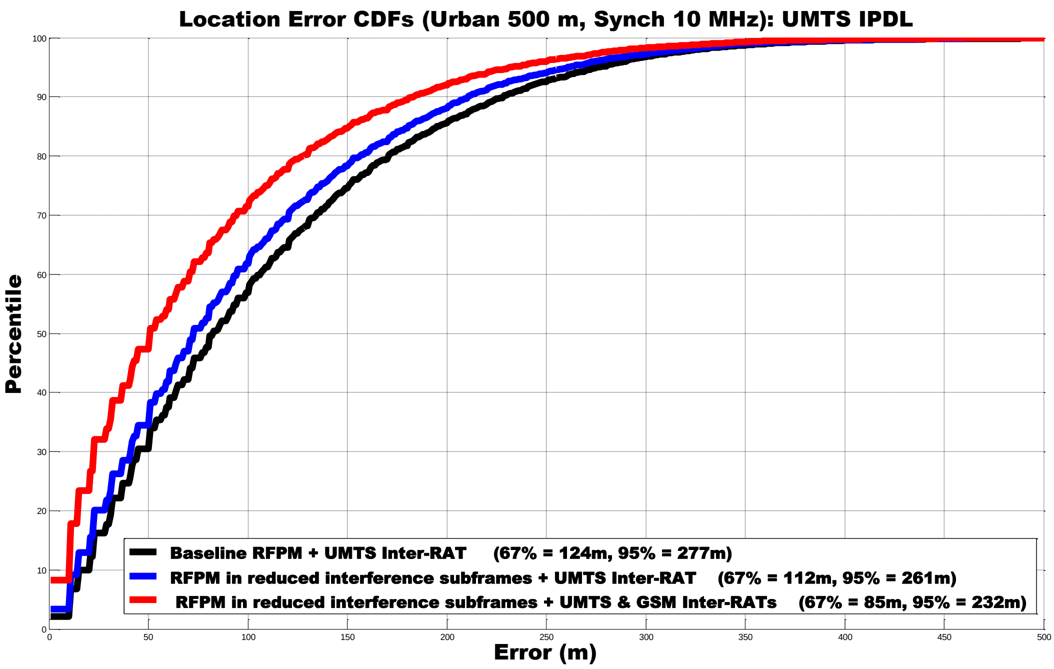


Figure 7.1-7: Polaris Wireless Simulation Results for UMTS inter-RAT with IPDL from R4-133620 [18]

7.2 Urban 1.4 MHz bandwidth case

One result for this case is in Figure 7.2-1. The absolute performance is degraded due to the lower bandwidth, however, the relative improvements for each of the studied scenarios remains consistent with the 10 MHz scenario. Examining the 67th percentile error we see a decrease in the error of 39%, 20%, and 50% for scenarios 2, 3 and 4 respectively.

Table 7.2-1: Company average simulation results (Based on 1 company result)

Scenario	Urban (500 m ISD) 1.4 MHz	
	67th Percentile (meters)	95th Percentile (meters)
Baseline (Scenario 1)	200	383
Reduced Interference Subframe (Scenario 2)	122	271
GSM Inter-RAT (Scenario 3)	160	388
Reduced Interference Subframe and GSM Inter-RAT (Scenario 4)	100	227

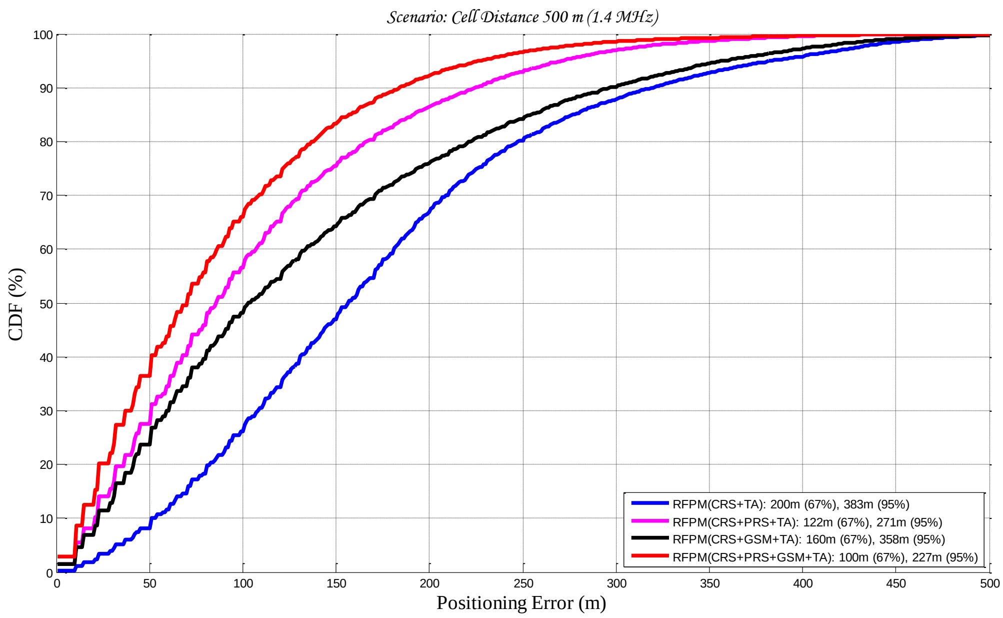


Figure 7.2-1: Alcatel-Lucent simulation results from R4-132371 [16] for low bandwidth, urban case

7.3 Suburban 10 MHz bandwidth case

One result for this case is presented in Figure 7.3-1 and summarized in Table 7.3-1. The absolute performance is degraded due to the larger cell spacing, however, significant gains are observed in each of the studied scenarios. Examining the 67th percentile error we see a decrease in the error of 47%, 23%, and 54% for scenarios 2, 3 and 4 respectively.

Table 7.3.1: Company average simulation results (Based on 1 company result)

Scenario	Suburban (1732 m ISD) 10 MHz	
	67th Percentile (meters)	95th Percentile (meters)
Baseline (Scenario 1)	715	1379
Reduced Interference Subframe (Scenario 2)	379	899
GSM Inter-RAT (Scenario 3)	551	1312
Reduced Interference Subframe and GSM Inter-RAT (Scenario 4)	330	832

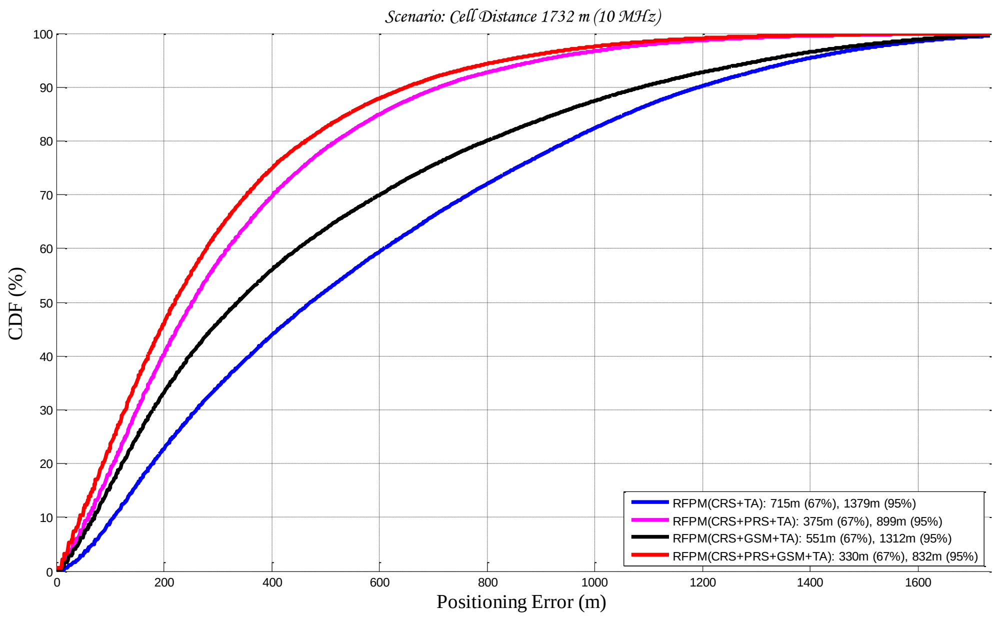


Figure 7.3.1: Alcatel-Lucent simulation results from R4-132371 [16] for high bandwidth, suburban case.

7.4 Suburban 1.4 MHz bandwidth case

One result is presented for this case in Figure 7.4-1 and summarized in Table 7.4-1. The absolute performance is degraded due to the larger cell spacing and lower bandwidth, however, significant gains are observed in each of the studied scenarios. Examining the 67th percentile error we see a decrease in the error of 45%, 19%, and 51% for scenarios 2, 3 and 4 respectively.

Table 7.4.1: Company average simulation results (Based on 1 company result)

Scenario	Suburban (1732 m ISD) 1.4 MHz	
	67th Percentile (meters)	95th Percentile (meters)
Baseline (Scenario 1)	731	1409
Reduced Interference Subframe (Scenario 2)	403	884
GSM Inter-RAT (Scenario 3)	592	1326
Reduced Interference Subframe and GSM Inter-RAT (Scenario 4)	357	818

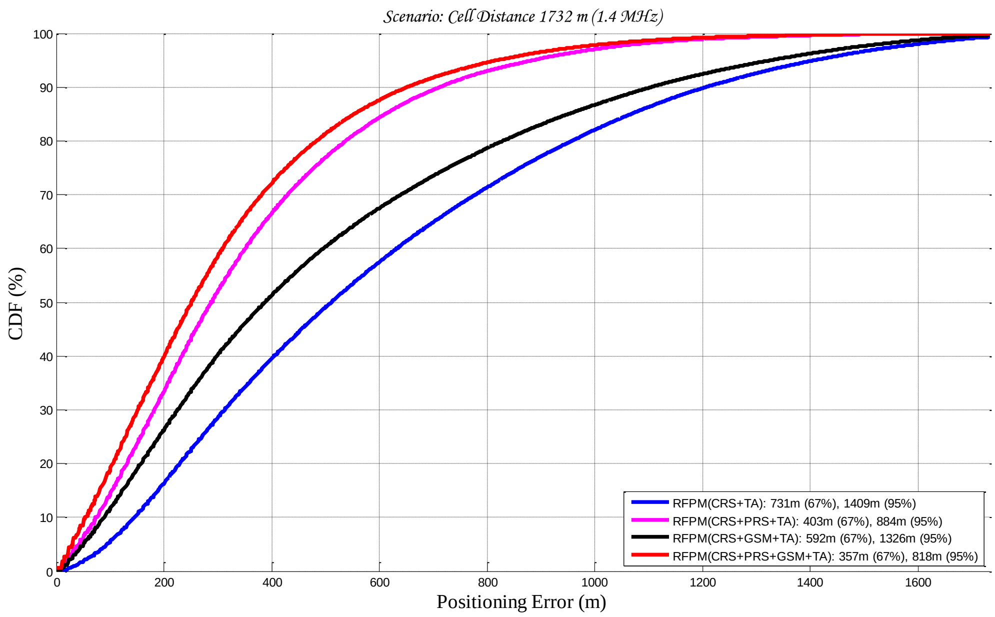


Figure 7.4.1: Alcatel-Lucent simulation results from R4-132371 [16] for low bandwidth, suburban case

7.5 Urban 10 MHz bandwidth case with 50 meter bins

The last case studied examines the effects of changing the resolution of the underlying grid used to model the network. In this case, the resolution is changed from 10 meters to 50 meters for a 10 MHz bandwidth urban network.
The increased bin size yields a slightly degraded performance. This result is perhaps expected due to the increased quantization error introduced by moving to larger grid spacing. However, the relative improvement offered by each studied enhancement holds.

Table 7.5.1: Company average simulation results (Based on 1 company result)

Scenario	Urban (500 m ISD) 10 MHz	
	67th Percentile (meters)	95th Percentile (meters)
Baseline (Scenario 1)	211	444
Reduced Interference Subframe (Scenario 2)	131	403
GSM Inter-RAT (Scenario 3)	167	407
Reduced Interference Subframe and GSM Inter-RAT (Scenario 4)	118	381
UMTS Inter-RAT (Scenario 5)	163	415
Reduced Interference Subframe and UMTS Inter-RAT (Scenario 6)	113	332
UMTS Inter-RAT with IPDL (Scenario 8)	121	397
Reduced Interference Subframe and UMTS Inter-RAT with IPDL (Scenario 9)	104	294

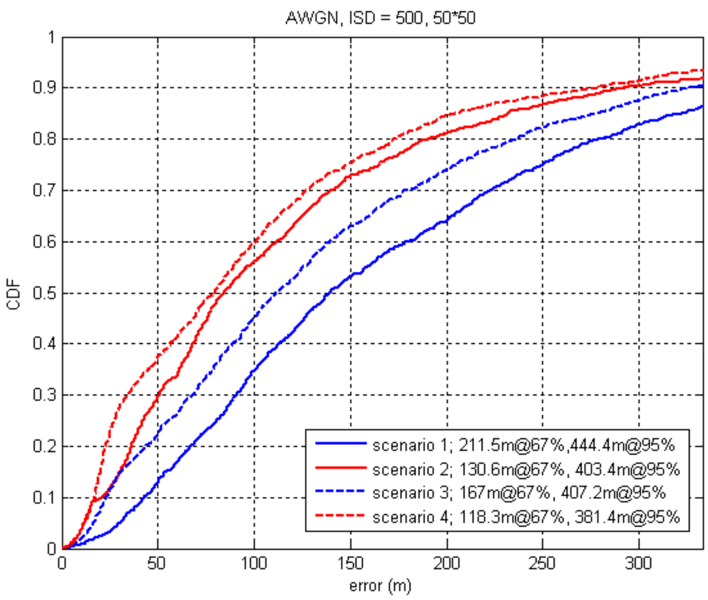
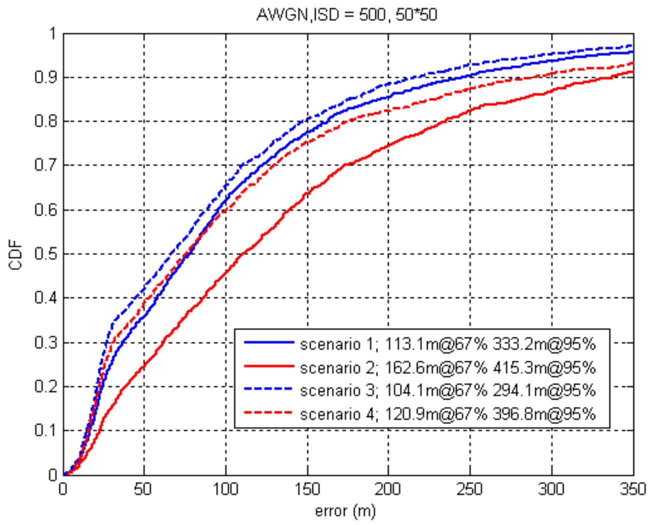


Figure 7.5-1: Huawei simulation results from R4-130636 [15] for 50 meter grid



NOTE: Scenarios 1,2,3, 4 in this figure correspond to scenarios 5,6,8 and 9 respectively.

Figure 7.5.2: Huawei simulation results from R4-133575 [17] for 50 meter grid and UMTS inter-RAT

8 Impact to the E-UTRA specifications

The basic RFPM functionality is already possible to support by implementation, based on the existing positioning measurements and procedures standardized since 3GPP Rel-9.

In addition, two key enhancements have been evaluated in this study:

(1) Signal measurements during reduced interference subframes

(2) Inclusion of Inter Radio Access Technology (Inter-RAT) measurements

8.1 Signal measurements during reduced interference subframes

There are several approaches that can be used to support this enhancement.

To enable positioning measurements in reduced-interference subframes, the UE would need to know when such subframes occur and adapt its measurements accordingly.

Positioning subframes is one example of reduced-interference subframes. Positioning subframes are configured via LPP for RSTD measurements with OTDOA positioning. With the current standard, however, the UE is not expected to perform RSRP or UE Rx-Tx measurements in such positioning subframes only, even when the positioning subframe configuration is known to the UE via LPP.

ABS subframes in heterogeneous deployments is another example of reduced-interference subframes. Measurement resource restriction patterns are configured via RRC and once the UE is configured with such a pattern, it would perform the RSRP and UE Rx-Tx measurements accordingly. Thus, requesting RSRP, RSRQ, or UE Rx-Tx measurements for E-CID via LPPa by positioning node and then configuring the measurements and a measurement resource restriction pattern via RRC by the serving eNodeB is a possible implementation solution.

Thus, the RFPM enhancement based on reduced interference subframes in the form of ABS subframes used for RFPM seems to be already possible with LPPa-based E-CID positioning via implementation, with no additional standard impact. A shortcoming of this implementation may be that not all UEs supporting E-CID positioning may be supporting measurements in ABS subframes.

Using positioning subframes for E-CID which currently are used for OTDOA only would provide more flexibility but would also require some protocol changes to either the E-CID or OTDOA positioning method defined in 3GPP TS 36.355 [11] and 3GPP TS 36.455 [10] along with an update to the stage 2 positioning specifications in 3GPP TS 36.305 [9].
It would also need to be decided whether the signal measurements in positioning subframes would be performed based on CRS or PRS.

8.2 Addition of inter-RAT measurement reporting

The second enhancement that has been evaluated also has multiple implementations.
The inter-RAT measurement reporting could be standardized as a part of E-CID positioning method.
From the signalling and protocol procedure enhancement perspective, if this is done in LPPa, there is an impact on 3GPP TS 36.455 [10] and 3GPP TS 36.305 [9]. If this enhancement is to be specified for LPP, there is a corresponding impact on 3GPP TS 36.355 [11] and 3GPP TS 36.305 [9], 3GPP TS 36.355 [11].
In both ways, there is also an impact on UE complexity, which needs to be further assessed, and potentially UE requirements in 3GPP TS 36.133 [8].
Extending the inter-RAT capability to include UMTS measurements made during IPDL would require some additional changes at least to 3GPP TS 36.331 [14], 3GPP TS 36.355 [11], 3GPP TS 36.455 [10], and 3GPP TS 36.133 [8].

9 Conclusions

The basic RFPM functionality is already possible to support by implementation, based on the existing positioning measurements and procedures standardized since 3GPP Rel-9.

This study focused on two enhancements to RFPM in LTE:

(1) LTE measurements performed in reduced-interference subframes;

(2) LTE measurements combined with additional inter-RAT measurements.

Each proposed enhancement effectively improves the positioning geometry by providing additional measurements. When the UE makes measurements in reduced interference conditions the number of observable or hearable neighbours is improved significantly. Such reduced interference subframes already exist, e.g., in LTE OTDOA positioning in the form of positioning subframes in which Positioning Reference Signals (PRS) may be transmitted.

Similarly, using inter-RAT measurements not only adds additional measurements but the measurements are from a different radio access technology that may have a significantly different interference environment than that of the LTE network, improving the positioning geometry.

Based on average results, the gains with LTE measurements in reduced-interference conditions are up to 30% and the gains from using GSM measurements are up to 23%. Using UMTS measurements show similar gains to that of GSM.

Based on these results the following recommendations are made:

- Rel-12 to include that E-CID RSRP and RSRQ measurements are performed in positioning subframes, to exploit the lower interference conditions. Such measurements shall be optional for the UE.

- Rel-12 to include support for inter-RAT measurements for E-CID positioning method such that inter-RAT measurements are optionally available for the purposes of positioning.

It is worth noting that, although this study focused on RFPM positioning, the above enhancements have a potential to improve the performance of any positioning technique that uses the E-CID positioning procedures and protocols.

Annex A: RFPM location estimation algorithm

An example location estimation approach that may be used for RFPM is described below.

Assume that we have a predicted database of RSRP and TA measurements for a 2 dimensional set of locations (pixels). Given a measurement vector, we will compute the following expression for each pixel:

$$\frac{\| rsrp\_meas\_vec - rsrp\_pred\_vec \|^2}{\sigma_{rsrp}^2} + \frac{\| ta\_meas - ta\_pred \|^2}{\sigma_{ta}^2}$$

The denominators in the above expression denote measurement error variances and can be computed from the measurement error samples observed during link level simulations. The RFPM location estimate is then the location of the pixel that minimizes the above expression.

Annex B: Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2011-10	RAN4#60 bis	R4-115169			Skeleton	N/A	0.1.0
2012-03	RAN4-63	R4-121102			Implementation of TP R4-121102 .Simulation Methodology and Parameters Editorial changes include change of the update version to 0.2.0, change of the table of contents, and removal of unnecessary/placeholder references In addition, the document contains additional modifications to TP R4-121102 at RAN4-63 to align with scope of SI	0.1.0	0.2.0
2013-04	RAN4-66	R4-131760			Reflects release 12 schedule Added Scope. Updated evaluation methodology to focus on system level simulations. Updated the agreed upon simulation scenarios and corresponding parameters	0.2.0	0.3.0
2013-05	RAN4-67	R4-133026			Updated References Updated General description of RF Pattern Matching Updated LTE architecture for RF Pattern Matching Added Simulation scenarios and results	0.3.0	0.4.0
2013-08	RAN4-68	R4-134357			Modified Simulation parameters to include UMTS Added UMTS simulation scenarios and general observations to clause 7 Added details to clause 8 "Impact to the E-UTRA Specifications" Added Conclusions Provide details to Annex A: RFPM Location Estimation Algorithm	0.4.0	1.0.0
2013-08	RP-61	RP-131155			Submitted v100 to RAN#61 for 1-step approval	1.0.0	1.0.0
2013-08	RP-61	RP-131240			Submitted v101 to RAN#61 for 1-step approval	1.0.0	1.0.1