Abstract—This paper presents the methodology of defining the measurement trigger conditions and evaluation conditions of LTE cell reselection for Release 9 capable UEs. In the proposal of cell reselection parameters, the RSRQ measurement quantity is considered to account for the increase of packet traffic in LTE networks. In addition, the proposal is designed to improve the end user experiences such as the LTE camp-on ratio, the avoidance of unnecessary cell reselection measurements causing the battery drain and the ping-pong effect between LTE and WCDMA inter-RAT cell reselection or redirection. The cell reselection parameter proposal is made based on the field test data collected in Tokyo metropolitan area.

Keywords—LTE release 9, cell reselection, RSRQ, idle mode parameters

I. INTRODUCTION

The UEs capable of 3GPP Release9 specification started emerging in the mobile phone markets in the world from 2013 and eventually Apple’s iPhone5s/5c and other latest smartphones have been also released stirring up lots of UE subscribers’ desire to purchase the LTE UEs. Even if the operators have not experienced high packet data traffic brought by the smart phones yet and do not have quantitatively measurable record to tell how much the packet traffic will increase by the LTE UEs, they can down to earth anticipate that the packet traffic volume in LTE RAN will arise significantly and shortly, which will end up with serious RSRQ deterioration in RF coverage perspective. In this case, the Release8 idle mode parameters for determining UE’s cell reselection behaviour [1], [2], which adopts only RSRP of the serving cell and the target cells, won’t be good enough in the high traffic network scenario and the operators will need the provision of Release 9 idle mode parameters to accommodate the RSRQ measurement quantity into idle mode cell reselection [3]. It is inferable that some operators have already revised their idle mode parameter settings in the preparation of release 9 LTE UE launch.

II. LTE IDLE MODE OPTIMIZATION FOR END USER EXPERIENCES

As in the WCDMA network where EcNo gets lower resulted from the increase of own cell traffic and/or other cell traffic, RSRQ in LTE network is also degraded when the traffic in the own cell and/or other cell grows. If UE’s cell reselection is performed only according to RSRP but not to RSRQ, which is Release 8 version, UE won’t be able to perform the cell reselection to a superior LTE target layer cells even if the serving cell’s RSRQ went to a significantly low level due to high traffic. As a result, the end user will experience poor packet performance if RRC connection is started.

RSRQ driven cell reselection becomes crucial in case there is a possibility that the LTE traffic would not be equally distributed over the multiple LTE layers. For example, if an operator is running multiple LTE frequency bands where the eNB’s antenna for each LTE frequency band is located in different spots resulting in each eNB posing different RF coverage footprints or even if the eNBs for each frequency band forms the similar RF coverage layout, RSRQs won’t be the similar level in case the eNB vendors do not support traffic load balancing feature over multiple LTE bands. Also if the eNB vendors are different for each frequency band, the load balancing between the multi-vendor are not generally supported and as a result, RSRQ of the different frequency bands could be far different from each other even if RSRP levels are similar.

Cell reselection is performed according to the system information parameters broadcasted in SIB3, SIB5, SIB6 of LTE and SIB19 of WCDMA. The new parameters additionally provided in Release 9 in the SIBs are summarized in Table 1 [3],[4].

<table>
<thead>
<tr>
<th>SIB Type</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIB3</td>
<td>s-IntraSearchP-r9</td>
</tr>
<tr>
<td></td>
<td>s-IntraSearchQ-r9</td>
</tr>
<tr>
<td></td>
<td>s-NonIntraSearchP-r9</td>
</tr>
<tr>
<td></td>
<td>s-NonIntraSearchQ-r9</td>
</tr>
<tr>
<td></td>
<td>q-QualMin-r9</td>
</tr>
<tr>
<td></td>
<td>threshServingLowQ-r9</td>
</tr>
<tr>
<td>SIB5</td>
<td>q-QualMin-r9</td>
</tr>
<tr>
<td></td>
<td>threshX-HighQ-r9</td>
</tr>
<tr>
<td></td>
<td>threshX-LowQ-r9</td>
</tr>
<tr>
<td>SIB6</td>
<td>threshX-HighQ-r9</td>
</tr>
<tr>
<td></td>
<td>threshX-LowQ-r9</td>
</tr>
<tr>
<td>SIB19 (WCDMA)</td>
<td>qualMinEUTRA</td>
</tr>
<tr>
<td></td>
<td>threshXhigh2</td>
</tr>
<tr>
<td></td>
<td>threshXlow2</td>
</tr>
</tbody>
</table>

It is aimed in this paper to propose the cell reselection parameters taking into account the traffic load increase (RSRQ measurement quantity) for LTE network. The target UE model
of the new cell reselection parameters is the Release 9 capable
UEs. In the new cell reselection parameter proposal, the
RSRQ threshold for the measurement trigger and the
evaluation condition are investigated. The test area where the
new cell reselection parameters are developed is dense urban
areas in Tokyo with high packet traffic.

III. END USER’S IDLE MODE PERFORMANCE IN LTE NETWORK

The LTE network operator’s objective for idle mode is to
have the LTE capable UEs hold the LTE coverage as long as
possible showing ‘4G’ or ‘LTE’ symbol on the mobile’s
screen. The assessment of how long or how high chance of
camping on the LTE cells rather than 3G cells can be
articulated by a performance indicator called ‘LTE camp-on
ratio’, which is the ratio of the LTE data samples against
the 3G data samples collected by UE. The LTE camp-on ratio is
determined by the parameters relevant to the S-criteria and the
evaluation condition for LTE to WCDMA cell reselection.

As the 1st step of defining the UE’s measurement trigger for
the cell reselection, it is considered the end user idle mode
performance, which is interpreted as the number of LTE signal
bars displayed on the UE’s screen. Although the relation
between the number of signal bars and the packet call
performances may need to be studied separately however, in
general if the number of signal bars displayed is ‘3’ or more,
the LTE coverage can be considered acceptable or satisfying
level from end user’s perspective. Then, it is worthy to study
how the UE’s signal bars are determined upon LTE coverage
condition. iPhone5 was used for this investigation.

In order to study the relation between the number of the
signal bars and the actual RF coverage – RSRP and RSRQ, the
field test using iPhone5 and RF scanner was performed. The
RSRP and RSRQ measured by the scanner and the number of
signal bars data collected from the iPhone5 at the same time
stamp are compared for the same PCI that the iPhone5 was
camped on in idle mode.

Figure 1. shows that RSRP = -90dBm is apparent threshold
by which the signal bar 3 is determined in iPhone5. It can be
said that serving cell’s RSRP shall be greater than or equal to
90dBm to meet the end user’s RF coverage satisfaction, which
is signal bar 3 on screen.

\[ RSRP_{\text{serving}} \geq -90\text{dBm for signal bar 3} \] (1)

IV. DEFINING RSRP AND RSRQ THRESHOLDS FOR
MEASUREMENT TRIGGER

UE’s measurement for intra-frequency and inter-frequency
cell reselection shall be triggered at least before reaching
RSRP = -90dBm. In general, in the areas nearby the serving
cell’s antenna site, the RSRP level must be good enough not
requiring the cell reselection to the neighboring cells and also
the neighbor cell’s RSRP condition is not at the comparable
level to the serving cell’s. At the cell edge or cell border areas,
the serving cell’s RSRP and RSRQ must be deteriorated due
to the propagation loss and noise and other cell interferences.
It can be re-written that the cell reselection measurement
trigger at the serving cell’s edge needs to be triggered with
high certainty that the serving cell’s RSRP will not fall below
-90dBm. The definition of serving cell edge is expressed as
follow in this paper.

\[ \Delta RSRP = RSRP_{\text{serving}} - RSRP_{\text{neighbor}} \leq 3\text{dB} \] (2)

It is noted from Figure 2. that the ratio of cell edge, defined
by \( \Delta RSRP \), against the overall data samples is slightly less
than 20% at RSRQ = -10dB. However, when the RSRQ is
-9dB or higher, the ratio of cell edge sample is negligible and
in adverse, the inner area samples where no suitable neighbor
cell for cell reselection can be found approaches almost 100%.
9dB causes unnecessary cell reselection triggers to occur too often and therefore, it is desirable to use -10dB for the RSRQ threshold for Release 9 UE’s measurement trigger.

\[ RSRQ_{\text{serv}} \leq -10dB \quad (3) \]

The next step is to define the measurement trigger threshold of RSRP for release 9 UE. The lower bound of RSRP has been defined as -90dBm. The upper bound for RSRP, shall be determined in a way that UE can avoid the unnecessary measurements for intra-frequency and inter-frequency neighbors. The PDF distribution of RSRP and RSRQ measured by RF scanner is presented in Figure 3.

Figure 3. PDF of RSRP and RSRQ in a dense urban area LTE network

The ‘X-zone’, shown in Figure 3., is the data samples where the cell reselection measurement won’t be triggered for the given RSRP and RSRQ thresholds. (e.g. RSRP and RSRQ threshold was given as -84dBm and -10dB respectively)

From this network measurement data, it is calculated in TABLE 2 how much ratio, the cell reselection measurement will occur at the cell edge and inner areas within the cell’s whole coverage when the different RSRP thresholds were used. In this calculations, RSRQ threshold is fixed to -10dB.

TABLE 2. INTRA-FREQUENCY MEASUREMENT RATIO AT THE CELL EDGE AND INNER AREAS FOR DIFFERENT RSRP

<table>
<thead>
<tr>
<th>RSRP [dBm]</th>
<th>Intra Cell Measurement Area (inner area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-80</td>
<td>75%</td>
</tr>
<tr>
<td>-84</td>
<td>65%</td>
</tr>
<tr>
<td>-88</td>
<td>60%</td>
</tr>
<tr>
<td>-92</td>
<td>55%</td>
</tr>
</tbody>
</table>

The higher the measurement ratio at the cell edge while the lower measurement ratio in inner area, the better cell reselection efficiency we aim to have. When RSRP = -84dBm is selected for the trigger threshold, we can avoid unnecessary measurements in the inner area while having 92% of cell edge area be subject to the measurement trigger.

Therefore, it is recommended to set the thresholds of RSRP for the release 9 UE’s intra-frequency cell reselection measurement trigger as follow:

\[ RSRP_{\text{serv}} \leq -84dBm \quad (4) \]

The cell reselection measurement for the inter-frequency neighbors of which priority is equal to or lower than the serving LTE layer, needs to be triggered marginally later than the intra-frequency measurement by 2dB. Therefore it is suggested to define the inter-frequency cell reselection measurement as below:

\[ RSRP_{\text{serv}} \leq -86dBm \text{ or } RSRQ_{\text{serv}} \leq -12dB \quad (5) \]

V. DEFINING RSRP AND RSRQ THRESHOLDS FOR EVALUATION CONDITION

When the target inter-frequency LTE layer or target inter-RAT 3G layer is lower priority than the serving LTE layer, there are three variants of cell reselection evaluation conditions for the release 9 capable UE. For Release 9 UE with \textit{threshServingLowQ} provided:

\[ RSRQ_{\text{serv}} < Q_{\text{qualmin}} + \text{Thresh}_{\text{ServingLowQ}} \]

\[ \text{AND } RSRQ_{\text{neighbor}} > Q_{\text{qualmin}} + \text{Thresh}_{\text{LowQ}} \]

\[ RSRQ_{\text{serv}} < Q_{\text{qualmin}} + \text{Thresh}_{\text{ServingLowQ}} \]

\[ \text{AND } E_{\text{c}/N_{\text{neighbor}} > Q_{\text{qualmin}+TRA}} + \text{Thresh}_{\text{XLowQ}} \]

, where \( Q_{\text{qualminoffset} } \) is assumed to be ‘0’.

For Release 9 UE without \textit{threshServingLowQ} provided:

\[ RSRP_{\text{serv}} < Q_{\text{extmin} + \text{Thresh}_{\text{ServingLowP}}} \]

\[ \text{AND } RSRP_{\text{neighbor}} > Q_{\text{extmin} + \text{Thresh}_{\text{LowP}}} \]

\[ RSRP_{\text{serv}} < Q_{\text{extmin} + \text{Thresh}_{\text{ServingLowP}}} \]

\[ \text{AND } RSRP_{\text{neighbor}} > Q_{\text{extmin+TRA} + \text{Thresh}_{\text{LowP}}} \]

, where \( Q_{\text{extminoffset} } \) is assumed to be ‘0’.

If the inter-frequency LTE layer has the same priority than the serving LTE layer does, the evaluation condition is given as below:

\[ RSRP_{\text{neighbor}} + Q_{\text{offset}} > RSRP_{\text{serv}} + Q_{\text{hysts}} \quad (10) \]

It is known from all the evaluation conditions expressed above that RSRQ measurement quantity is used for release 9 UE with \textit{threshServingLowQ} parameter provided in SIB3. Since it is aimed to develop an inter-frequency cell reselection evaluation condition taking into account the traffic load not only the RF coverage, RSRQ based evaluation condition needs to be investigated.

The RSRQ evaluation threshold for the serving LTE cell, \( Q_{\text{qualmin} + \text{Thresh}_{\text{ServingLowQ}}} \), defines the lower bound of LTE coverage that if RSRQ gets worse than this value, UE will perform inter-RAT cell reselection to WCDMA (assumed that WCDMA coverage is always higher than the lower bound
of WCDMA coverage of evaluation condition). In order to determine the RSRQ evaluation threshold, it is noted that there is another lower bound of RSRQ in spite it is not in idle more but in the RRC connected mode by which EUTRAN can release the RRC connection by force and to redirect the UE to WCDMA if RSRQ gets lower than this value. This parameter in connected mode is called a2-threshold [5]. The parameter value of a2-threshold provided in the rrcConnectionReconfiguration message governs UE’s measurement report of event A2.

When RSRQ is worse than a2-threshold due to high traffic load or high interference, it is reckoned that LTE throughput performance is no more superior to 3G’s so that the network configures in EUTRAN to redirect the UE to 3G network. It means that even if the evaluation threshold, ‘Q_{qualmin} + \text{Threshold}_{Serving,Lowq}’ for serving LTE cell is far lower than a2-threshold, in other words, UE did not make cell reselection to WCDMA even RSRQ is far lower than a2-threshold, the UE will be redirected to 3G once the UE enters the RRC connected mode. Therefore it is desirable to set the same RSRQ value for the evaluation threshold, ‘Q_{qualmin} + \text{Threshold}_{Serving,Lowq}’ as a2-threshold value.

The next step is to determine the value of Threshold_{X,Lowq}, which is used in the target cell’s evaluation condition. This parameter is also used in both inter-frequency and inter-RAT cell reselection evaluations. The parameter, Threshold_{X,Lowq} is a sort of hysteresis to avoid the ping-pong that UE comes back to the old serving cell’s layer soon after the inter-frequency LTE cell reselection was made. The parameter, Threshold_{X,Lowq} needs to be defined so as to be less sensitive to the instantaneous fluctuation of RSRQ.

The stationary RSRQ measurement was performed at a station of Tokyo city to grab how much RSRQ level fluctuates. The measurement result is presented in RSRP and RSRQ fluctuation range in urban stationary test.

![RSRP and RSRQ fluctuation range in urban stationary test](image)

Figure 4. RSRP and RSRQ fluctuation range in urban stationary test

It is revealed that 90% of RSRQ samples centred on the median resides within 3.5dB fluctuation range. RSRP’s fluctuation range is 5dB as reference information.

Taking into account 3dB RSRQ fluctuation range, the target layer’s RSRQ shall be higher than serving layer’s RSRQ by 3dB or 4dB. 4dB of Threshold_{X,Lowq} could be too high to satisfy the evaluation condition for the target cell. Therefore, it is recommended to use 3dB and as a result the parameter value of Threshold_{X,Lowq} is defined as:

\[ \text{Threshold}_{X,Lowq} = \text{Threshold}_{Serving,Lowq} + 3dB \]

By deciding the parameter values of Threshold_{Serving,Lowq} and Threshold_{X,Lowq}, the evaluation condition utilizing RSRQ is completed.

VI. CONCLUSIONS

The cell reselection parameters for release 9 capable UE proposed in this paper can be various depending on the operator’s strategy of LTE network deployment and the absolute layer priorities between the LTE layers and WCDMA. Nevertheless, the presented procedure and the methodology used in this paper can be reused in any LTE networks with a certain degree of customizations. Using the proposed values, 8% of unnecessary cell reselection measurement trigger could be avoided and 22% of the end user perception of LTE coverage during the idle mode could be improved in Tokyo metropolitan area.

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