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ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

Optimized Scaling Factor for Cell Change Parameters for Speedy Users in LTE

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Abstract

Long Term Evolution (LTE) supports mobility using cell reselection and handover processes. The parameters affecting the time to trigger cell reselection and handover are scaled for high mobility users. The present method allows to vary the scaling in a very few steps. A novel method is proposed in the paper which can vary the scaling with more granularities. The signal quality fluctuates significantly with user speed in the conventional method but the proposed method can satisfactorily stabilize the signal quality. The proposed method allows optimized settings for scaling based on the scenario.

(Keywords: Hysteresis, Scaling, cell reselection, handover)

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Chapter 1

Introduction

1.1 context, problem and solution

Long term evolution (LTE), based on a 3GPP standard is the latest step in the evolution of cellular services. In case of LTE, the service is continued as the user moves out of the coverage of one cell and enters the coverage of another cell and thus, mobility is supported. The decision for the change of cell depends on the relative radio link quality between the current cell and the neighbor cells at the position of the UE. The mobility is supported using cell reselection or handover. In the RRC_IDLE state, if the UE changes the cell on which it is camped, the cell reselection procedure is performed. On the other hand, in the RRC_CONNECTED state, if the serving cell changes, then the handover procedure is performed. When the UE moves at very high speed, it passes through many cells in short period of time. Then in order to maintain the good quality of service, a lesser delay in triggering cell reselection and handover is required. This is because a large delay in change of cell would let the UE move too away from the old serving cell resulting in very low received power or even service disruption. The E-UTRAN configures certain parameters in order to set the delay appropriately. There is a provision for scaling such parameters for high mobility users with a view to retain the quality of service and avoid any disruption of services. The amount of the scaling depends on how quickly the UE is changing the cells (i.e. the user speed). However, the present method allows the variation of the scaling in only a few steps. This paper proposes a novel way to vary the scaling with more granularities. It allows adapting the delay in triggering cell reselection and handover very well with the user speed. As a result, the cell reselection and handover occurs at a more appropriate moment before the received power falls too low. The lowest experienced signal level becomes more independent of the user speed due to more granularities in scaling.

1.2 Cell Change Parameters for Speedy UEs

A number of parameters are involved in cell reselection and handover processes and some of them are used for adaption with the user speed. Apart from the Normal-Mobility State supporting UEs at low speed, High-Mobility State and Medium-Mobility State are defined. The UE determines its appropriate mobility state based on the number of cell reselections or handovers during certain time as shown below. The associated parameters T_{CRmax}, $T_{CRmaxHyst}$, N_{CR_M} and N_{CR_H} are configured by the E-UTRAN. The UE does not take consecutive reselections between the same two cells into account while detecting the mobility state since consecutive reselections or handovers between the same two cells do not reflect the speed of the UE in a particular direction.

- *High-Mobility State:* The UE enters high-mobility state if there are more than N_{CR_H} numbers of cell reselections or handovers in T_{CRmax} duration.
- *Medium-Mobility State:* The UE enters medium-mobility state if there are more than N_{CR_M} number of cell reselections or handovers but less than N_{CR_H} number of cell reselections in T_{CRmax} duration.
- *Normal-Mobility State:* The UE stays in normal-mobility state if the parameters, T_{CRmax}, N_{CR_H}, N_{CR_M} and $T_{CRmaxHyst}$ are not sent by the E-UTRAN. When they are sent, the UE enters normal- mobility state from medium-mobility or high-mobility state if neither medium-mobility state nor high-mobility state is detected during time period $T_{CRmaxHyst}$.

Chapter 2

Existing model

2.1 EXISTING MODELS OF CELL SELECTION

2.1.1 Cell reselection

In RRC_IDLE state, if the UE changes the cell on which it is camped, then cell reselection process occurs. While a UE is camped on a cell in the RRC_IDLE state, it attempts to operate on the best quality RF carrier available at its present location. Therefore, it keeps on checking on neighboring cells around itself. If it finds a neighbor cell better than the serving cell such that the cell reselection conditions are fulfilled, the UE itself selects the new cell without notifying the network; this process is known as cell reselection. As the UE has no resources allocated to it by the network in the RRC_IDLE state, notifying the network will cause wastage of wireless resources and power. This procedure can involve a change of RAT.

A cell is termed SUITABLE CELL, when the UE obtains normal service with a valid USIM (Universal subscriber identity module).during this state, the UE engages itself in the cell reselection process to find out the best neighbor cell to camp on, and meanwhile, the UE keeps a list of neighboring cells which meet the cell reselection criteria and keeps on monitoring these cells on a regular basis [1]. The eNodeB does not provide the UE with any list of neighboring cells to consider for cell reselection. All the steps taken for cell reselection is done solely by the UE alone.

The frequencies for the interfrequency and inter-RAT cell reselection are specified on SIB types and the UE uses these frequencies. In addition, the SIB types assign relative priorities to these frequencies using the CellReselectionProirity IE. Such priorities help in spreading users among different collocated frequencies in the same cell. The CellReselectionProirity IE can have any integer value from 0 through 7 and its higher value is interpreted as a higher priority. The E-UTRAN and any other RAT cannot be assigned the same priority. Specific dedicated priorities can be optionally assigned to a UE when the UE enters the RRC_IDLE state from RRC_CONNECTED state using the RRCConnectionRelease message. These priorities can be deleted and re assigned as the UE moves between RRC_IDLE and RRC_CONNECTED state. The priorities of the RRCConnectionRelease message override the priorities of SIB type 5, SIB type 6 and SIB type 7. The UE applies the priority information on the RRCConnectionRelease message for the T320 timer period after the RRC connection release. It includes the T320 timer value and the value can be 5, 10,20,30,60,120 or 180 minutes. When the UE receives the RRCConnectionRelease message, it starts the T320 timer. When the T320 timer expires, the UE starts applying cell reselection priority information provided in the SIB.

The cell reselection condition does not incorporate the Srxlev of the serving cell, so it may be the case that Srxlev of the neighbor cell is lower than that of the serving cell. The UE considers the reselection to neighbor cells of the current E-UTRAN frequency and equal priority interfrequency neighbor cells evaluating the rank of the serving cell and the neighbor cells. To avoid too many cell reselections a hysteresis is applied to the rank of the serving cell. For reselecting a new cell, the cell has to be better than the serving cell by the hysteresis that is configurable by the network. In addition, an amount of offset is applied to the rank of the neighbor cell, which allows biasing the reselection toward particular cells. The rank of the serving cell and neighbor cells are calculated frequently as follows:

The rank of the serving cell, $Rs = Q_{meas's} + Q_{hyst}$

The rank of the neighbor cell, $Rn = Q_{meas'n} - Q_{offset}$

The UE reselects to a new intrafrequency and equal priority interfrequency cell if the new cell stays higher ranked than the serving cell for the duration $Treselection_{RAT}$. If more than one neighbor cell is higher ranked, the UE reselects to the highest ranked cell. A separate $Treselection_{RAT}$ timer is started for each cell that becomes better ranked than the serving cell. If the $Treselection_{RAT}$ timer expires for any cell when it is the highest ranked, the UE triggers cell reselection to that cell.

Now, the $Q_{meas's}$ and $Q_{meas'n}$ are the RSRP (reference signal receive power) measured by the UE on the serving cell and on the neighbor cell respectively. Q_{hyst} is the hysteresis applied to the rank of the serving cell, whose value can be 0,1,2,3,4,5,6,8,10,12,14,16,18,20,22 or 24 db. The value for Q_{offset} for both intrafrequency and interfrequency can be any of the following: -

24,-22,-20,-18,-16,-14,-12,-10,-8,-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6,8,10,12,14,16,18,20,22 or 24 dB.

The LTE attempts to ensure good performance at high speed. And this can be done by allowing less stringent cell reselection conditions through the reduction of the values of Q_{hyst} and $Treselection_{RAT}$. The UE determines its appropriate mobility state based on the number of cell reselections during a certain time. The UE enters a high- mobility state if there is more than N_{CR_H} number of cell reselections in the T_{CRmax} duration. It enters a medium-mobility state if there are more than a N_{CR_M} number of cell reselections but less than a N_{CR_H} number of cell reselections in the T_{CRmax} duration. The UE stays in normal-mobility state if the parameters T_{CRmax}, N_{CR}, N_{CR_M}, and $T_{CRmaxHyst}$ are not sent in the system information. When they are sent, the UE enters the normal-mobility state from the medium-mobility state or the high-mobility state if neither of these states is detected during the time period $T_{CRmaxHyst.}$

SIB type3 contains the SpeedStateReselectionPars IE, which includes the MobilityStateParameters IE. The values of $T_{CRmaxHyst}$ and $T_{CRmaxHyst}$ can be 30, 60,120,180 or 240 seconds. The values of N_{CR_M} and N_{CR_H} can be any integer up to 16. When normal-mobility state is detected the UE does not modify any parameters. However, if the high-mobility state or the medium-mobility state is detected, the UE modifies the value of the Q_{hyst} and the Treselection.

The hysteresis, Q_{hyst} applied to the rank of the serving cell is reduced for speedy users. Thus, a lesser difference between the signal levels of the serving cell and the new cell can satisfy the cell reselection conditions leading to a quicker cell reselection. The SpeedStateReselectionPars IE includes Q-HystSF IE (speed-dependent Scaling Factor for Qhyst). Q-HystSF includes the SF-High and SF-Medium fields. They both can take on any of the following values: -6,-4,-2 or 0 dB. When the high-mobility state or the medium-mobility state is detected, Q_{hyst} is decreased by adding SF-High or SF-Medium, respectively, to Q_{hyst}.

The cell reselection takes place when certain conditions are found to be fulfilled for the duration, $Treselection_{RAT}$. Therefore, the $Treselection_{RAT}$ is decreased is reduced by a scaling factor for speedy UEs in order to allow a quicker cell reselection. The value of each of these scaling factors is given by the SpeedStateScaleFactor IE, which includes the SF-High and SF-Medium fields. These fields can have the values 0.25, 0.5, 0.75 or 1. When high-mobility or medium-mobility state is detected, $Treselection_{RAT}$ for the particular RAT is decreased by multiplying by the corresponding SF-High or SF- Medium, respectively.

2.1.2 reduction of Q_{hyst} and $Treselection_{RAT}$ for speedy UEs

LTE attempts to ensure good performance even at a high speed. When the UE moves at a very high speed, it passes through many cells in short period of time. Thus it requires changes of serving cells too frequently. In this case, the good quality of radio link can be maintained if the UE can switch the serving cell as soon as the signal from the new cell starts getting better than the signal from the old cell. This achieved by allowing less stringent cell reselection conditions through the reduction of values of Q_{hyst} and $Treselection_{RAT}$. Also, the higher the speed of the UE is, the less stringent the cell reselection conditions should be. Therefore, apart from the normal-mobility state supporting UEs at a low speed, the high-mobility state and medium-mobility state are defined in order to improve performance for UEs at a very high speed and a medium-high speed, respectively. Thus, the following three different states of mobility are defined for the UE:

- High-mobility state: the UE enters a high-mobility state if there is more than N_{CR_H} number of cell reselections in the T_{CRmax} duration.
- Medium-mobility state: the UE enters a medium-mobility state if there are more than a N_{CR_M} number of cell reselections but less than a N_{CR_H} number of cell reselections in the T_{CRmax} duration.
- Normal-mobility state: the UE stays in a normal-mobility state if the parameters $T_{CRmax,}$ N_{CR_H}, N_{CR_M}, and $T_{CRmaxHyst}$ are not sent in the system information. When they are sent, the UE enters the normal-mobility state from the medium-mobility state or high-mobility state if neither the medium-mobility state nor high-mobility state is detected during the time period $T_{CRmaxHyst}$.

The values of T_{CRmax} and $T_{CRmaxHyst}$ can be 30, 60,120,180 or 240 seconds. The values of N_{CR_M} and N_{CR_H} can be any integer up to 16. If normal-mobility state is detected the UE does not modify any parameters. However, if the high-mobility state or the medium-mobility state is detected, the UE modifies the values of Q_{hyst} and $T_{reselection}$ as shown below:

- Q_{hyst}: The hysteresis, Q_{hyst}, applied to the rank of the serving cell, is reduced for speedy UEs. Thus, a lesser difference between the signal levels of the serving cell and the new cell can satisfy the cell reselection conditions leading to a quicker cell reselection. The SpeedStateReselectionPars IE includes Q-

HystSF IE (speed-dependent ScalingFactor for Q_{hyst}). Q-HystSF includes the SF-High and SF-Medium fields. They both take on only negative values. Their values can be -6, -4, -2 or 0 dB. When the high-mobility state or medium-mobility state is detected, Q_{hyst} is decreased by adding SF-High or SF-Medium, respectively, to Q_{hyst}.

- $T_{reselectionRAT}$: The cell reselection takes place when certain conditions are found to be fulfilled for the duration, $Treselection_{RAT}$. Therefore, it is reduced by a scaling factor for speedy UEs in order to allow a quicker cell reselection. The value of each of these scaling factors is given by the SpeedStateScaleFactors IE. The SpeedStateScaleFactors IE includes the SF-High and SF-Medium fields. These two fields can take on values 0.25, 0.5, 0.75 or 1. When the high-mobility state or the medium-mobility state is detected, $Treselection_{RAT}$ for the particular RAT is decreased by multiplying by the corresponding SF-High or SF-Medium, respectively.

2.2 Existing Model of Handover

2.2.1 Handover

In the RRC_CONNECTED state, the mobility of the UE is supported through the only procedure, handover between eNodeBs.The handover is always hard handover as it uses break-before-approach. Since soft handover is not supported, only a single radio link can exist between the UE and the network.

Types of Handover

The handover can be classified based on the involvement of a change of RAT as follows:

1. **Intra-E-UTRAN handover**: The handover takes place between two E-UTRAN cells.

2. **Inter-RAT handover**: The handover takes place between an E-UTRAN cell and a cell of a RAT other than LTE e.g. GERAN, UTRAN and CDMA2000

Handover can be categorized as soft, softer, or hard.

• **Soft and softer handover**: Soft and softer handovers are characterized by “make-before-break.” The connection to the new cell is established before the connection to the previous cell is broken. Softer handover occurs when multiple radio links exist between the UE and different cells belonging to the same Node B. Softer handover is established with the UE in the same procedure as a soft handover,

The set of cells with which the UE is in soft handover r is called the Active Set. UTRAN sends the Active Set Update message to add or remove cells from the Active Set. This is called Active Set Update Procedure. The UE assists in the process by taking signal strength measurements of the neighbor cells and reporting this to UTRAN, but ultimately UTRAN decides when to perform Active Set Update.

• **Hard handover**: Hard handovers are characterized by “break-before-make.” The connection to the previous cell is broken before the connection to the new cell is established. This causes a brief interruption in voice or data communication, while making the transition from the old serving link to the new. Hard handover is used for a variety of reasons, including:

 Inter-frequency handover: It is always hard handover since the mobile must tune away from the old serving frequency to the new frequency.

 Inter-RAT handover: It is always hard handover.

 Physical Channel Reconfiguration: Certain reconfigurations of the physical channel, such as a timing change, require a hard handover. Note that this may or may not include a change of

Node B or cell, but will require that the radio link be broken and reestablished.

 RNC to RNC Handover: If the Iur interface is not supported, then a handover between NodeBs connected to different RNCs is a hard handover

<u>Intra-E-UTRAN handover</u>

The intra-E-UTRAN handover can be classified based on the interface used for handover initiation as follows. However, from the perspective of the UE, these two types of handover appear to be the same.

1. **X2-based-handover:**

If there is an X2 interface interconnecting the source eNodeB and the target eNodeB, then the handover procedure typically uses the X2 interface. In this case, the source eNodeB and the target eNodeB belong to the same MME. The X2-based handover procedure differs slightly in the two following cases:

- The handover does not change the serving GW.
- The handover changes the serving GW.

2. S1-based handover:

The handover between E-UTRAN cells takes place using the interfaces that interconnect the source eNodeB and the target eNodeB with their MMEs, typically when the X2 interface cannot be used. This may happen in the following cases:

- The X2 interface does not exist between the source eNodeB and the target eNodeB.
- A change of the MME and/or a change of the serving GW is required and the source eNodeB is configured to use the S1 interface because of this change .In this case, the source eNodeB and the target eNodeB may belong to different tracking areas.
- The target eNodeB rejects the attempt of the source eNodeB to initiate handover using the X2 interface.

  The S1-based handover may involve a change of the MME, or not, depending on the change of the location of the UE. Also , if the MME changes ,then the S1-based handover may or may not involve a change of the serving GW.

The intra-E-UTRAN handover can also be classified based on the scenario for handover as follows:

1. UE-assisted handover:

This is the typical type of handover .It provides for network-controlled and UE-assisted mobility .The UE performs measurements of the radio linl quality of serving and neighbor calls and sends measurement reports to the network.The network considers the radio link quality reported and makes the decision for the handover.This is often referred to as backward handover because it uses exchange of information over the radio link with the old eNodeB.

2. **Blind handover:**

The network makes a decision of handover without depending on any measurement reports from the UE. The blind handover can be quickly performed due to the avoidance of any measurements, so it can be used when the delay in handover is undesired. However, the radio link quality at the new cell is uncertain .The blind handover typically occurs to move a user from a heavily loaded cell to a lightly loaded cell the purpose of load balancing.

3. **Radio link failure (RLF) handover:**

This handover procedure is UE-based .In order to improve the success of the RLF handover, multiple target eNodeBs can be prepared simultaneously for handover .Then source eNodeB performs handover preparation phase with multiple potential target eNodeBs instead of only one .The source eNodeB performs the handover execution phase with only one target eNodeB. If there is failure in the signaling related to handover because of a poor radio link ,the UE selects a suitable E-UTRA cell from the prepared ones. Then the UE can establish an RRC connection with this cell promptly. Since the RRCConnectonReestablishmentRequest message includes the C-RNTI of the UE and PCI of the source cell. The new target eNodeB can detect the source eNodeB. Then the new target eNodeB can obtain the UE context from the source eNodeB. Then this new target eNodeB can obtain the UE context from the source eNodeB. The Reestablishment procedure cause field in the RRCConnectonReestablishmentRequest message which indicates that handover failure has triggered the RRC connection reestablishment procedure. After successful handover with the new target eNodeN, it sends the UE CONTEXT RELEASE message to the source eNodeB. Then the source eNodeB may indicate cancellation to the other prepared eNodeBs.

A variant of the RLF handover is the forward handover. The forward handover procedure is also UE-based. It is performed when the serving eNodeBs has a radio link too poor to allow it to duly receive measurement reports from the UE. Then unlike the typical RLF handover, the serving eNodeB fails to prepare any target eNodeBs for handover .Despite no target eNodeB prepared for handover, the UE can choose and access an eNodeB on its own and thus conduct forward handover.

Inter-RAT handover:

The inter-RAT handover takes place between an E-UTRAN cell and a cell of GERAN, UTRAN, or CDMA2000. The source eNodeB uses the S1 interface to initiate the inter-RAT handover. The inter-RAT handover can be classified as follows:

1. UE-assisted handover:

It is network controlled and UE assisted handover. The UE performs measurements of the radio link quality of the serving cell and inter-RAT neighbor cells and sends measurement reports to the network. The network considers the radio link quality reported and makes the decision for handover.

2. Blind handover: The network makes a decision of handover without depending on any measurement reports from the UE. The blind handover typically occurs for the purpose of circuit-switched fallback (CSFB) because the reduction of call setup delay is crucial in CSFB.

3. RLF handover: The RLF handover can also be inter-RAT.IN this case, the UE selects a cell using another RAT e.g. GERAN or UTRAN.

The inter-RAT handover procedure differs slightly in the following two cases:

- The handover does not change the serving GW.
- The handover change the serving GW.

2.2.2 Measurment Reporting

A measurement reporting configuration is identified by its ID. The UE trigger measurement reporting in either two ways:

1. Event-triggered: The UE begins sending measurement reports when any of the particular events takes place. The UE is considered to enter a particular event when a certain conditions are met. Similarly, the UE is considered to leave a particular event when certain conditions are met. As long as the event remains activated, the UE keeps on sending a maximum number of measurement reports. The network specifies entering and leaving conditions for the various events, the interval between measurement reports, and the maximum number of measurement reports to be sent. Actually there are five types of events for measurement reporting of E-UTRA cells.

- Event A1: The serving cell becomes better than a threshold
- Event A2: The serving cell becomes worse than a threshold
- Event A3: The neighbor cell between better than the serving cell by an offset
- Event A4: The neighbor cell becomes better than a threshold.
- Event A5: The serving cell becomes worse than a threshold ,threshold 1, and the neighbor cell becomes better than another threshold ,threshold 2.

There are two types of events for the measurement reporting of inter-RAT cells ,such as:

- Event B1: The neighbor cell becomes better than a threshold.
- Event B2: The serving cell becomes worse than a threshold and the neighbor cell becomes better than another threshold.

2. Periodical: The UE sends measurement reports regardless of the satisfaction of any conditions. The UE keeps on sending the measurement reports one after another at a certain interval until it reaches a maximum number of measurement reports. The network specifies the interval between measurement reports to be sent.

When the eNodeB adds or modifies a measurement reporting configuration ,it includes the ReportConfigToAddModList IE in the MeasConfig IE. The ReportConfigToAddModList IE includes the ReportConfigToAddModList IE for each reporting configuration .The ReportConfigToAddMod IE includes the ReportConfigId IE, which specifies the ID of the measurement reporting configuration. A new ID is assigned for new measurement reporting. The ID can be any integer number up to 32.

E-UTRA Measurement Reporting:

If the measurement objects is an E-UTRA frequency, then the ReportConfigToAddMod IE includes the ReportConfigEUTRA IE in order to configure measurement reporting.

Parameters for Both Event-Triggered and Periodical Measurement Reporting

The ReportConfigEUTRA IE includes the following fields that are applied to both event-triggered and periodical measurement reporting cases:

- Trigger Type: This field specifies if the measurement reporting is event-triggered or periodical.
- TriggerQuantity: This field specifies if the UE would send measurement reports in terms of RSRP or RSRQ.
- ReportQuantity: This field can have the value “SameAsTriggerQuantity” or “Both”. If its value is set to “SameAsTriggerQuantity” then the UE sends measurement reports in terms of RSRP or RSRQ as specified by Trigger Quantity. If the value is set to “Both” then the UE sends measurement reports in terms of RSRP and RSRQ.
- ReportAmount: This field specifies the maximum number of measurement reports to be sent by the UE .Its value can be 1,2,4,8,16,32,64 or infinity.

When the value of ReportAmount is infinity, the UE keeps on sending measurement reports until any reporting condition changes.

- Report Interval: This field gives the length of the interval between measurements reports. It can be 120,240,480,640,1024,2048,5320 or 10240 ms or 1, 6, 12, 30, or 60 minutes.
- MaxReportCells: This field specifies the maximum number of neighbor cells to be included in the measurement report. It can be any integer up to 8.

Event-Triggered Measurement Reporting

The ReportConfigEUTRA IE includes the following fields in the case of event-triggered measurement reporting to specify the criteria for sending measurement reports in addition to the aforementioned common fields:

- **TimeToTrigger**: This field specifies the period during which the specific criteria for a particular event need to be met in order to trigger the measurement reporting .Its value can be 0,40,64,80,100,128,160,256,320,480,512,640,1024,1280,2560,or 5120 ms.
- **Hysteresis**: This IE specifies the value of hysteresis ,which is used for the determination of the entering condition and leaving condition for a particular event-triggered measurement reporting .The value of hysteresis is calculated as (the IE value × 0.5) dB, where the IE value can be any integer up to 30.
- **Threshold**: This IE gives the threshold value for a particular event-triggered measurement reporting as follows:
    - A1-Threshold: The value of threshold for Event A1
    - A2-Threshold:The value of threshold for Event A2
    - A4-Threshold:The value of threshold for Event A4
    - A5-Threshold:The value of threshold 1 for Event A5
    - A5-Threshold:The value of threshold 2 for Event A5

All the threshold values are given using the following IEs:

- RSRP_Range: This IE is used for the value of threshold if the measurement reports are made in terms of RSRP value can be any integer up to 97.
- RSRQ-Range: This IE is used for the value of threshold if the measurement reports are made in terms of RSRQ .Its value can be any integer up to 34.

- **A3-Offset**: This IE gives the offset value to be used in the case of Event A3.The value of offset is calculated as (the IE value × 0.5) dB,
- **ReportOnLeave**: these 1-bit field indicators if the UE would send a measurement report when the leaving condition for an event is met.

Periodical Measurement Reporting

In order to configure periodical measurement reporting, the ReportConfigEUTRA IE includes the purpose IE .In addition to the aforementioned common fields. The purpose IE indicates if this measurement reporting is for the purpose of handover decision or ANRF .The purpose IE can take on any of the following values:

1. **ReportStrongestCells**: The measurement reporting is for the purpose of handover decision. The UE keeps on sending the measurement reports one after another periodically until it reaches the specified number of measurement reports.
2. **ReportCGI**: The measurement reporting is for the purpose of ANRF to discover the identity of certain cells. The MeasObjectEUTRA IE includes the CellForWhichToReportCGI IE, which contains the PCI of the cells for which the UE is required to attempt for the acquisition of the ECGI.

   Since ,in this case ,the purpose is reporting the identity of certain cells and not the radio link quality ,the UE sends measurement report only once .Thus, the value of ReportAmount is considered 1..

Inter-RAT Measurement Reporting

If the measurement is an inter-RAT frequency, then the ReportConfigToAddMod IE includes the ReportConfigInterRAT IE in order to configure measurement reporting.

Parameters for Both Event-Triggered and Periodical Measurement Reporting

The ReportConfigInterRAT IE incudes the following fields that are applied to both event-triggered and periodical measurement reporting cases:

- **TriggerType**: This field specifies if the measurement reporting is event-triggered or periodical.
- **ReportAmount** : This field specifies the maximum number of measurement reports to be sent by the UE. Its value can be 1,2,4,8,16,32,64 or infinity .When the value of ReportAmount is infinity, the UE keeps on sending measurement reports until any reporting condition changes (e.g. the leaving condition for an event is met).

- **ReportInterval**: This field gives the length of the interval between measurement reports .It can be 120,240,480,640,1024,2048,5120 or 10240ms or 1,6,12,30 or 60 minutes.
- **Max ReportCells**: This field specifies the maximum number of neighbor cells to be included in the measurement report. It can be any integer up to 8 to acquire the RAC of the GERAN cell. System Information type 3 contains the MCC, MNC ,LAC and RAC .

  Since, in this case, the purpose is reporting the identity of certain cells and not the radio link quality the UE, sends measurement report only once .and not the radio link quality, the UE ,sends measurement report only once.

  Thus, the value of ReportAmount is considered to be 1.

3. **Report StongestCellsForSON:** This is used for the network to detect and report the strongest UTRAN cell for the purpose of self –optimized networks (SON).It is currently not used for the GERAN network.

   Since, in this case, the purpose is to repeat a detected UTRAN cell, the UE sends the measurement report only once and reports only the cell decreased. Thus, both the values of MaxReportCells and ReportAmount are considered to be 1.

2.2.3 Reduction of TimeToTrigger for Speedy UEs:

When the UE moves at aver high speed in the RRC_CONNECTED state, it passes through many cells in a short period of time .Thus, it requires handovers too frequently ,so ,similar with the case ,the good quality of radio link can be maintained if the handover takes place as soon as the signal from the new cell starts becoming better than the signal from the old cell. Therefore, the UE should trigger measurement reporting quicker, and this is achieved by reducing the value of TimeToTrigger for event –triggered measurement reporting. The values of TimeToTrigger in no the ReportConfigInterRAT IE and the ReportConfigEUTRA IE, are reduced and the reduction is made he same way as using the same IEs of MobilityStateParameters and SpeedStateScaleFactors.

The UE determines its appropriate mobility state baaed on the number of cell reselections during certain time .However ,consecutive handovers between the same two cells do not reflect the speed of the UE in a particular direction .so the UE does not take consecutive reselection between the same two cells into account while detecting the mobility state.

- **High-mobility state**: The UE enters a high mobility state if there are more than N_{CR_H} numbers of handovers in the T_{CRmax} duration.
- **Medium-mobility state**: The UE enters the medium –mobility state if there are more than N_{CR_M} numbers of handovers but less than N_{CR_H} numbers of handovers in the T_{CRmax} duration.
- **Normal-mobility state**: The UE stays the normal-mobility state if the parameters T_{CRmax} , N_{CR_H} , N_{CR_M} , $T_{CRmaxHyst}$ are not sent .When they are sent ,the UE enters the normal-mobility state from the medium-mobility or high-mobility state if neither the medium-mobility state nor the high-mobility state is detected the time period $T_{CRmaxHyst}$.

The Meas Config IE contains the SpeedStatePars IE, which includes the MobiityStateParameters IE. The MobilityStateParameters IE includes the T-Evaluation , T-HystNormal, N-cellchangeMedium and N-CellChangeHigh fields for the detection of the Mobility state .

The SpeedStatePars IE includes the TimeToTrigger-SF IE whose value is given by SpeedScaleFactors IE. When the normal –mobility state is detected ,the UE does not modify TimeToTrigger, but when the high –mobility state or medium –mobility state is detected , TimeToTrigger is decreased by multiplying by SF-High or SF-Medium, respectively ,to allow the intended the quicker triggering of measurement reporting.

Chapter 3

SHORTCOMINGS OF EXISTING MODEL

The conventional procedure for cell reselection and handover tends to provide unsatisfactory radio link service, especially, in case of the speedy UEs. The main intention and purpose of cell reselection and handover is to complete the process before the level of received power stoops down too low, which may account for the discontinuity in cellular connection. As mentioned earlier the existing model categorizes velocity in normal-mobility state, medium-mobility state and high-mobility state. Then the existing model assigns particular values of different parameters such as Q_{hyst}, $Treselection_{RAT}$, Q_{offset}, TimeToTrigger, SpeedStateScaleFactor etc. to each state of velocity. The impact is that, the cell reselection and handover procedure takes a bit longer to perform. The reason for delay is that for speedy UEs the values of the parameters are not scaled according to their velocity. The same parameter value is used for the lower values of a mobility state as well as for the higher values of the same mobility state. The parameter values work convincingly for the lower values of a velocity range but for higher values of the same range it shows unsatisfactory performance. And eventually the cell switching occurs when the UE has travelled a considerable distance away from the serving cell to cause a reduction in received power when cell switching occurs. This reduction in received power during the time of cell switching may cause discontinuity in cellular connection.

In conventional method, not only the received power decreases to an alarmingly low level in the course of cell reselection and handover process, but also it tends to fluctuate with increasing distance from the serving cell. The received power fluctuation is prominent enough to cause disruptive and unsatisfactory radio link connection between UE and the network. It is necessary to maintain a stable radio link connection between UE and network for satisfactory cellular service.

The moment the received power from the serving cell becomes weak and the power from neighbor cells start to increase, the cell reselection and handover process needs to be initiated. These processes take a while to complete. In existing model, this process takes a significant amount of time which sometimes is enough to break the connection. In order to maintain a high quality radio link, the steps used in conventional methods needs to be faster.

Scaling factor is also used for the proposed model. But scaling is done based on the mobility state of the UE. For speedy UEs, this approach, sometimes result in the cellular discontinuity, as the scaling process for existing model is not fast enough and the parameter values which are set, are not suitable enough for speedy UEs.

Chapter 4

Proposed model

4.1 Cell reselection

The proposed model differs from the existing model in the context of velocity categorization. In the proposed model the categorization is eliminated and the scaling of different parameters is done based on the number of cell selections.in the proposed model, the UE movement is defined in different velocities but not in different range of velocities as opposed to the existing model. Then the number of cell reselection is determined based on the velocity. If the number of cell reselection becomes greater than N_{crmax}, then scaling of Q_{hyst} and Treselection is done using Q_{hyst}SF, N_{cr} and SpeedStateScaleFactor (SSSF). If the number of cell selections is less than N_{crmax}, then no scaling is required. The following stage involves calculation of distance from cell boundary where cell reselection is triggered. After the initiation of cell reselection the rank of both serving cell and neighbor cell is calculated. The distance from cell boundary where R_N exceeds R_S is calculated. This distance is important to calculate to find out the triggering point of Treselection timer. Another purpose for calculating the distance where neighbor cell rank exceeds serving cell rank is to show that using the proposed model the cell reselection occurs faster, meaning that the cell reselection occurs when the UE has travelled less distance away from the serving cell. Making cell reselection to occur faster has the advantage of switching to a new cell when the received power signal is high. This high level of received power ensures that there is no chance of cellular discontinuity. In case of speedy UEs, while using the existing model, there is the probability of cellular discontinuity as the cell reselection occurs at a distance far away from the serving cell. So, for speedy UEs, to address the problem, cell reselection process needs to occur faster and at shorter distance away from serving cell.

Treselection timer runs for a predefined time (set by using scaling factor). It is important for the R_N to stay above R_S for that timer period. If it does not stay for the whole period then a new neighbor cell is selected. But if it does, then that neighbor cell is selected to be the next serving cell. The distance from cell boundary where Treselection timer expires is calculated.

Only after the expiration of Treselection, then cell reselection takes place. All these distances are calculated to find out the actual distance away from serving cell boundary where cell reselection takes place. Afterwards, the received power from old serving cell is measured at the position of cell reselection as minimum received power. This task is done to show that by using the proposed model, cell reselection takes place at higher received power than for existing model.

The proposed model also provides a novel idea to stabilize the fluctuations in received power which is prominent in the existing model. Fluctuations in received power result in disruptive cellular connection. The proposed model helps in providing uninterruptible cellular connection by stabilizing the fluctuation.

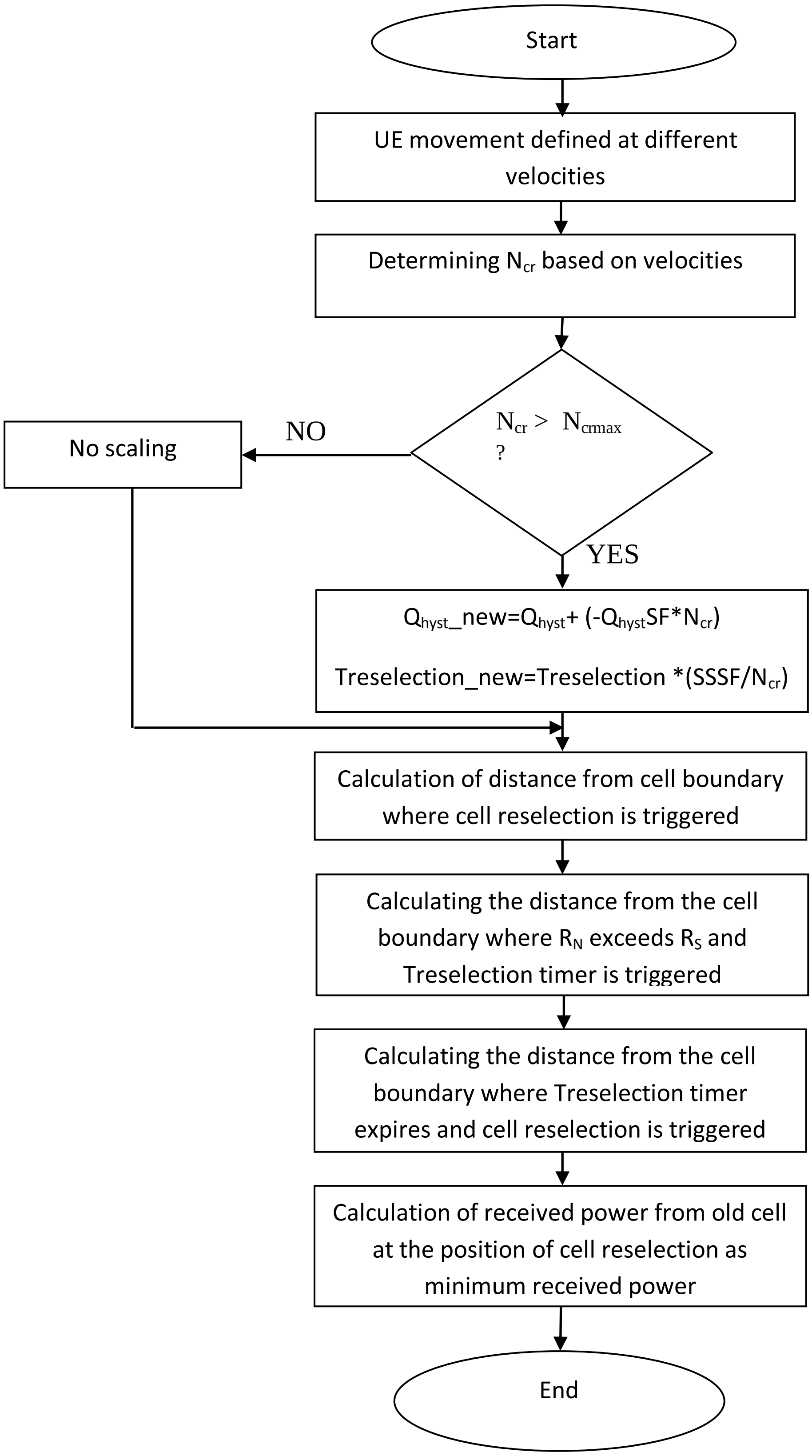

FIGURE 1: FLOW CHART FOR PROPOSED CELL RESELECTION MODEL

4.2 Handover

The proposed model for handover also differs from the existing handover model in the context of categorizing UE velocity. Here, the categorization of velocities is eliminated. The scaling of different parameters is done based on the number of cell reselections. Similar to proposed process of cell reselection, in handover also, at first the UE movement is defined in different velocities. Then based on these velocities, the number of cell selection is determined. If the number of cell selections is less than N_{crmax}, then no scaling is needed. Otherwise, scaling of the parameter TimeToTrigger is done by using SSSF and N_{cr}. In case of handover, there is no need to calculate the rank of both the serving cell and the neighbor cell. The existing model does not require the rank of serving cell and neighbor cell. So, in the proposed model also, calculation of rank of rank of serving and neighbor cell is not done.

Moreover, in handover, Treselection is not used also. As Treselection timer is used to observe whether R_N stays above the R_S for the duration of the timer, Treselection timer is not needed as rank of serving and neighbor cell is not calculated. Here, the rank of serving and neighbor cell is taken to be equal during the entire process of handover.

After the scaling, then the distance from cell boundary of serving cell is calculated where handover is triggered. The handover process consists mainly of sending measurement reports from the UE side to the network. The number of measurement reports is defined by the network. Only when the UE sends the required number of measurement reports, then network does the handover process. In the proposed model, the handover process is optimized by making it faster. In the proposed model, the time interval between sending each measurement report is decreased using the scaling factors. The parameter TimeToTrigger is decreased and as a result the time interval between sending each measurement report gets decreased in the process. As a result, shorter time is needed for the UE to send the required number of measurement reports. And eventually, the handover process takes place at a shorter distance away from the serving cell. But in the existing model, the time interval between each measurement report is long enough to cause the handover to trigger at a longer distance away from the serving cell boundary where the received power is low. This causes the discontinuity of the cellular connection. So the proposed model helps trigger the handover faster, at shorter distance away from the serving cell and at a power level which is high and eliminates the possibility of cellular discontinuity.

Moreover, the proposed model makes the fluctuation of received power stable. Fluctuations in received power result in disruptive cellular connection. The proposed model provides a novel approach to stabilize the fluctuation and ensures an uninterruptible cellular connection.

The following page consists the flow chart for proposed handover model in step by step process.

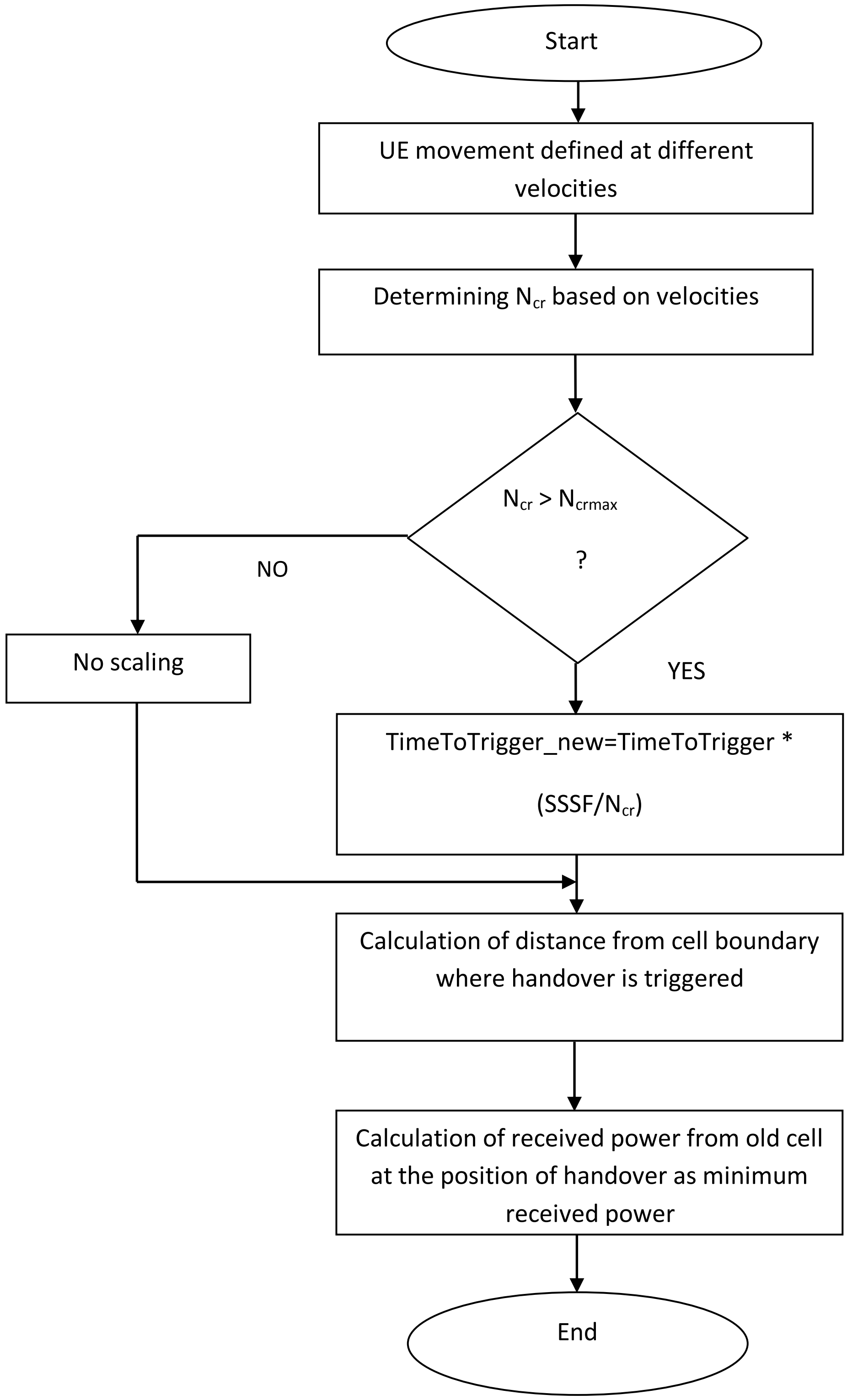

FIGURE 2: FLOW CHART OF PROPOSED HANDOVER MODEL

Chapter 5

Performance analysis

5.1Cell reselection

The table of parameter values used in the proposed model is given below

Q_{offset}	0
eirp	40
fc	750
htx(transmitter height)	30
hrx(receiver height)	1
Q_{hyst}_initial	10
Treselection_initial	6

Table 1: Parameters for cell reselection models

proposed1

Q_{hyst}_SF1	0.8
SpeedStateScaleFactors1	4
N_{cr}_init(i)	2
Q(i)	0
Treselec(i)	1

Table 2: Changed parameters for proposed model 1(CR)

Proposed2

Q_{hyst}_SF2	1
SpeedStateScaleFactors2	3
N_{cr}_init(i)	2
Q(i)	0
Treselec(i)	1

Table 3: Changed parameters for proposed model 2(CR)

Existing

N_{cr}_init(i)	4
Q2(i)	0
treslec2(i)	1
N_{cr}_init(i)	4
N_{cr}_init(i)	8
Q2(i)	0.75
Treselec2(i)	0.75
Q2(i)	-8
Treselec2(i)	0.25

Table 4: Parameters for existing model (CR)

The tables in this section give the parameter values which were used for both proposed and existing cell reselection process. Contents of table 1 were used for all four cases. Contents of table 2 and table 3 were used for the proposed cell reselection model 1 and 2 respectively. Contents of table 4 were used for existing cell reselection process. For proposed model 2 the

SpeedStateScaleFactor has been decreased and Q_{hyst} has been increased compared to parameters of proposed model 1. It will be seen that proposed model 2 yields better result.

To represent the model without any scaling, no scaling of parameter values has been used.

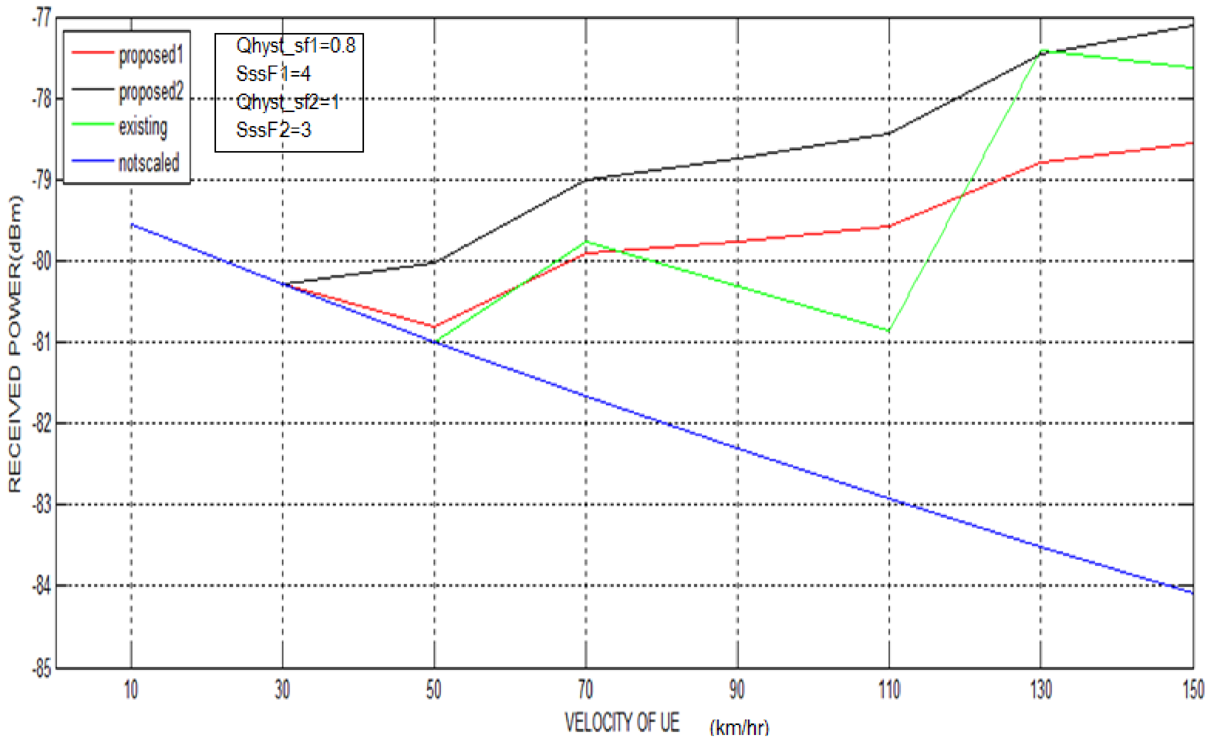

Figure 3: POWER VS VELOCITY CURVE OF PROPOSED CELL RESELECTION MODEL

Figure 3 shows the received power with respect to velocity. The graph shows the velocity starting from 10km/hr. as it was designed in this way.

The blue line represents the model without any scaling. Here, it is clearly evident that, without any scaling the received power decreases with the increase in velocity of the UE.

The green line represents the existing model. From the figure it is evident that the existing model shows great fluctuation in received power with the increase of velocity. The received power stoops up and down very sharply within a small margin of velocity change.

The black and red line represents the proposed model 2 and 1 respectively. Clearly, the proposed model 2 shows better result. It shows less fluctuation than proposed model 1 and the existing model. Moreover the received power does not stoop down too low. It always maintains a high value. Using the proposed model 2 optimum result can be obtained in cell reselection process. Proposed model 1 also shows less fluctuation than existing model. But from the figure it is clear that the received power becomes low than the existing model at some points. But the main intention and purpose is to keep the fluctuation stabilized, which can be achieved using the proposed model 1. This model can be used in cases, where high radio link quality is not required. Both the proposed models can achieve higher received power stability than the existing model. But when high radio link quality is required proposed model 2 is the perfect option and for low radio link qualities proposed model 1 will be the perfect option.

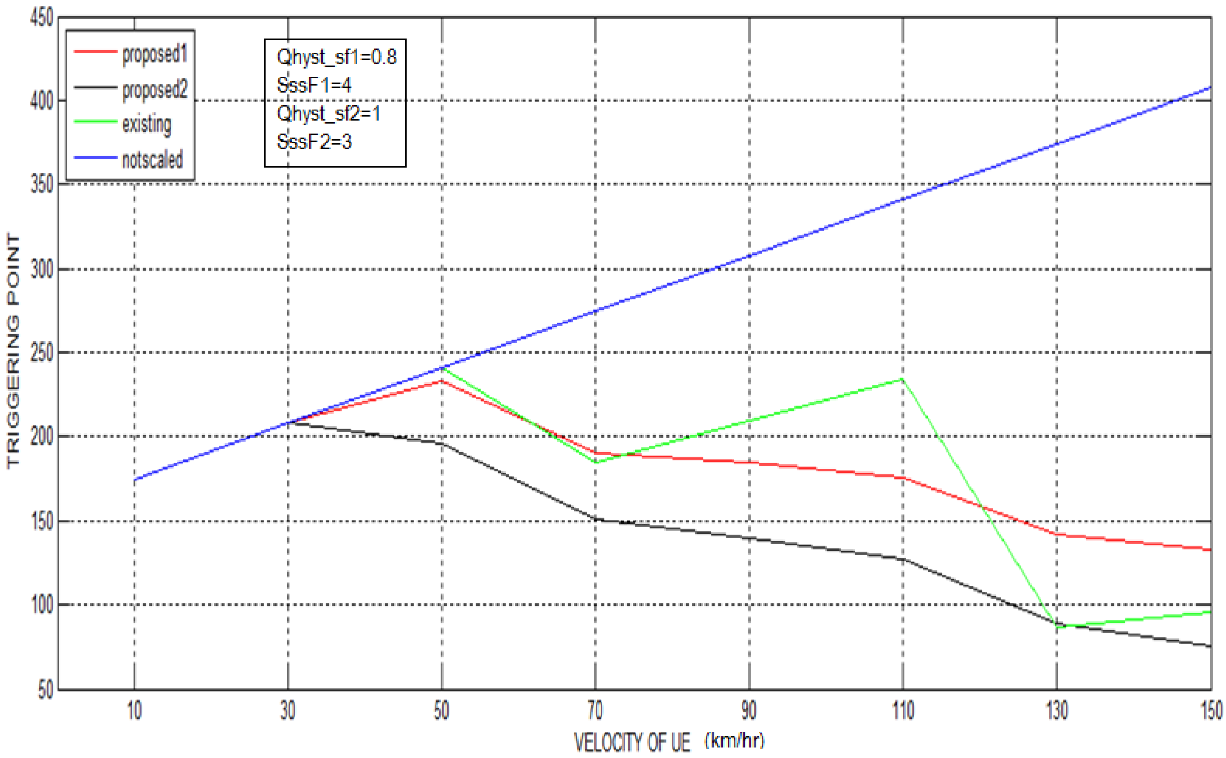

FIGURE 4: TRIGGERING POINT VS VELOCITY OF PROPOSED CELL RESELECTION MODEL

In figure 4, triggering point of cell reselection with respect to increase in velocity of the UE is shown. The graph shows the velocity starting from 10km/hr. as it was designed in this way.

The blue line shows the model without any scaling. It is visible from the figure that, as velocity increase the triggering point from the cell boundary increases as no scaling factor was used in this case.

The green line represents the existing model. As the velocity of the UE increases the triggering point decreases, but shows great fluctuation.

The black and red line shows the proposed model 2 and 1 respectively. As the velocity increases the decrease in triggering point for both the proposed models is more than the existing model. Moreover the proposed models do not show fluctuation which was very prominent in the existing model. Though at some points in the figure, proposed model 1 shows a slightly worse performance than the existing model, still it can be used in cases where high radio link quality is not required. Moreover, proposed model 1 also shows stability in fluctuation than the existing model.

So it is evident from the figure that, both the proposed models helps the triggering mechanism to function earlier than the existing model ensuring uninterrupted cellular connection. And the proposed models also show less fluctuation in the triggering points location ensuring smooth cellular connectivity.

5.2 HANDOVER:

The parameter values which were used for the proposed handover model is given in tables below

Q_{offset}	0
eirp	40
fc	750
htx	30
hrx	1
Q_{hyst}_initial	2
Treselection_initial	6
TimeToTrigger_initial	1.024
max_no_of_reports	5

Table 5: Parameters for handover models

proposed1

SpeedStateScaleFactors1	3

Table 6: Changed parameters for proposed model 1(HO)

Proposed2

SpeedStateScaleFactors2	1.5

Table 7: Changed parameters for proposed model 2(HO)

Existing

N_{cr}_init(i)	4
TimeToTrigger3(i)	0
N_{cr}_init(i)	2
N_{cr}_init(i)	7
TimeToTrigger3(i)	0.75
TimeToTrigger3(i)	0.25

Table 8: Parameters for existing model (HO)

The tables in this section give the parameter values which were used for both proposed and existing handover process. Contents of table 5 were used for all four cases. Contents of table 6 and table 7 were used for the proposed handover model 1 and 2 respectively. Contents of table 8 were used for existing handover process. For proposed model 2 the SpeedStateScaleFactor has been decreased compared to parameters of proposed model 1. It will be seen that proposed model 2 yields better result.

To represent the model without any scaling, no scaling of parameter values has been used.

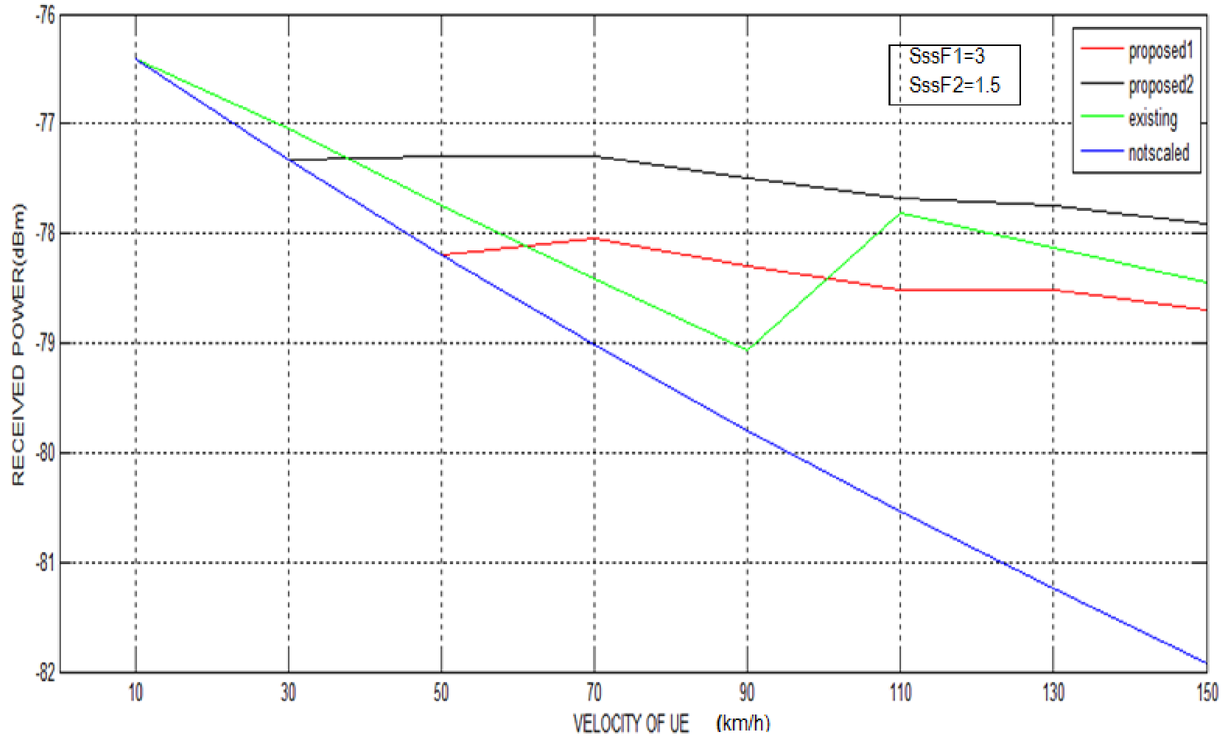

FIGURE 5: RECEIVED POWER VS VELOCITY OF PROPOSED HANDOVER MODEL

Figure 5 shows the received power with respect to velocity. The graph shows the velocity starting from 10km/hr. as it was designed in this way.

The blue line represents the model without any scaling. Here, it is clearly evident that, without any scaling the received power decreases with the increase in velocity of the UE.

The green line represents the existing model. From the figure it is evident that the existing model shows great fluctuation in received power with the increase of velocity. The received power stoops up and down very sharply within a small margin of velocity change.

The black and red line represents the proposed model 2 and 1 respectively. Clearly, the proposed model 2 shows better result. It shows less fluctuation than proposed model 1 and the existing model. Moreover the received power does not stoop down too low. It always maintains a high value. Using the proposed model 2 optimum result can be obtained in handover process. Proposed model 1 also shows less fluctuation than existing model. But from the figure it is clear that the received power becomes low than the existing model at some points. But the main intention and purpose is to keep the fluctuation stabilized, which can be achieved using the proposed model 1. This model can be used in cases, where high radio link quality is not required. Both the proposed models can achieve higher received power stability than the existing model. But when high radio link quality is required proposed model 2 is the perfect option and for low radio link qualities proposed model 1 will be the perfect option.

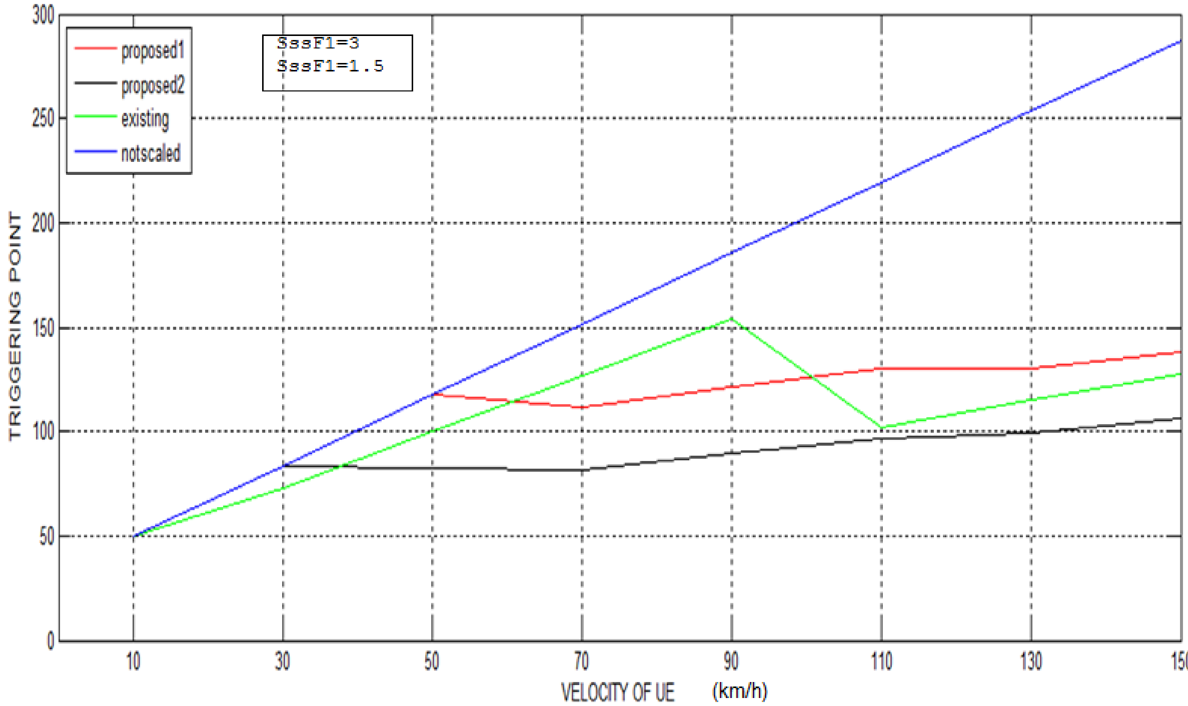

FIGURE 6: TRIGGERING POINT VS VELOCITY OF PROPOSED HANDOVER MODEL

In figure 6, triggering point of cell reselection with respect to increase in velocity of the UE is shown. The graph shows the velocity starting from 10km/hr. as it was designed in this way.

The blue line shows the model without any scaling. It is visible from the figure that, as velocity increase the triggering point from the cell boundary increases as no scaling factor was used in this case.

The green line represents the existing model. As the velocity of the UE increases the triggering point decreases, but shows great fluctuation.

The black and red line shows the proposed model 2 and 1 respectively. As the velocity increases the decrease in triggering point for both the proposed models is more than the existing model. Moreover the proposed models do not show fluctuation which was very prominent in the existing model. Though at some points in the figure, proposed model 1 shows a slightly worse performance than the existing model, still it can be used in cases where high radio link quality is not required. Moreover, proposed model 1 also shows stability in fluctuation than the existing model.

So it is evident from the figure that, both the proposed models helps the triggering mechanism of handover to function earlier than the existing model ensuring uninterrupted cellular connection. And the proposed models also show less fluctuation in the triggering point’s location ensuring smooth cellular connectivity.

Chapter 6

Conclusion

A novel idea has been proposed for better cell reselection and handover process. In this paper the changes done to the parameters of the existing model helps both the cell reselection and handover process to trigger faster. Moreover, it also shows that the power received from the old cell stays at a higher level during the time of cell reselection and handover trigger. Through computer simulation it has been shown that the proposed scheme performs better. The simulation result also shows that the proposed model performs exceptionally well with high mobility UEs.

APPENDIX

CR	Cell Reselection
HO	Handover
Hrx	receiver height
Htx	transmitter height
N_{CR_H}	number of cell selections_ high
N_{CR_M}	number of cell selections_medium
Q_{hyst}	Q hysteresis
$Q_{meas'n}$	Q measurement of neighbor cell
$Q_{meas's}$	Q measurement of serving cell
Q_{offset}	Q offset
RAT	Random Access Technology
R_N	rank of neighbor cell
R_S	rank of serving cell
SIB	system information block
SON	self-optimizing network
SSSF	SpeedStateScaleFactor
Treselection	Treselection timer
UE	user equipment

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