Horizontal Load Balancing Using Fuzzy Logic and Link Imbalance

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***Abstract* - Data needs on cellular networks are increasing at this time, one of which is triggered by 4G LTE Long Term Evolution technology, enabling LTE technology to have dynamic frequency aggregation, and generally the use of LTE technology uses a lot of frequency resources used. But on one hand 3G HSPA technology users are still quite a lot and the use of frequency for 3G HSPA becomes increasingly limited due to frequency resources optimized for 4G LTE technology. HSPA Dual Band does offer advantage by doubling throughput speed up to 42 Mbps with two channel aggregation in different band but with HSPA Dual Band activation followed by addition of Uplink Load. Therefore to keep improving the performance of the HSPA network can be done by Load Balancing method that can direct and divide traffic so that it can reduce the problems for site conditions that do have load uplink that will increase after the activation of Dual Band HSPA. By using a load balancing method that takes into account the imbalance link, the uplink load condition that becomes down or worse after the Dual Band HSPA activation can be reduced and avoided so that with Dual Band HSPA activation it does not make the exiting network conditions worse.**

Keyword - Dual Band HSPA, Uplink Load, Load Balancing, Link Imbalance.

I. INTRODUCTION

The development of cellular network technology is growing, triggered by 4G LTE technology (Long Term Evolution), but it is undeniable that 3G HSPA technology is still the choice of users, as seen in Figure 1 where 3G HSPA technology is still an option in Indosat West Java, where technology still contributes to data profiles as much as 40% to 45% based on [1].

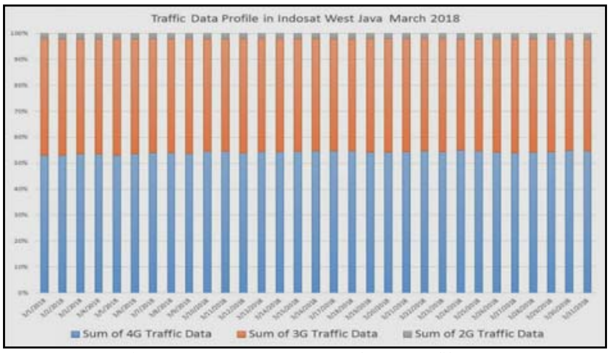

Figure 1 4G-3G-2G Data Volume Profile [1]

The evolution of HSPA can be one of the keys to radio access technology with the aim of efficiency of cellular operator costs. Multi-carrier HSPA is introduced to increase spectrum efficiency and reduce latency on the network. HSPA multi-carrier dual carrier or dual band system aims to increase the throughput of cells on the user side up to 42 Mbps [2] and illustrated in Figure 1. The system generally requires the aggregation of two carriers in the same frequency band, ie two carriers UMTS 2100. However, PT. Indosat, has the allocation of the UMTS 900 band as a third carrier so it seems as if the HSPA multi-carrier technique can not be implemented properly. Therefore, 3GPP Release 9 has defined rules that allow carrier aggregation in different frequency bands, for example the UMTS 2100 and UMTS 900 bands known as dual band (DB) HSPA. And as in the picture 2 pair aggregation UMTS2100 and UMTS900 are general or standard configurations for Dual Band HSPA according to Huawei system [3].

With HSPA Dual Band technology enabled [3] [4] uplink load resources will increase and this can make network performance decrease in the event of an uncontrolled uplink load addition.

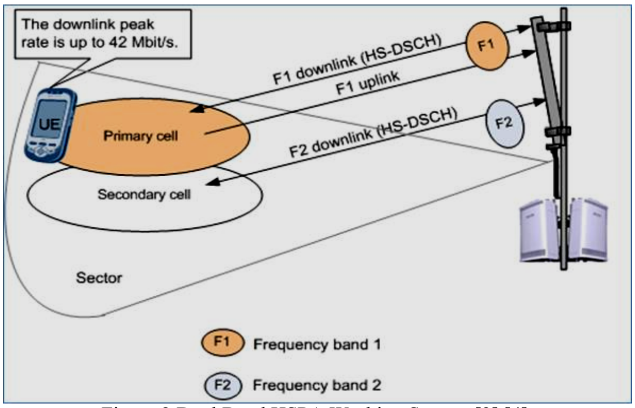

Figure 2 Dual Band HSPA Working System [3] [4].

It is undeniable that the development of HSPA cellular technology is quickly accompanied by all the new features, but the new features are not immediately applicable because analysis and simulation are needed that can be used as well as consideration factors not all networks are in ideal conditions, for example Dual HSPA Band (HSPA Multi carrier with two different frequencies). As an illustration the example of figure 2 shows the Dual Band HSPA working system where two frequencies can be put together and the example of Figure 3 shows the configuration of Dual Band HSPA for each type of frequency.

For figure 3 describe the basic configuration for Dual Band HSPA for different frequency carrier

DB-HSDPA Configuration	Combination of Frequency Bands	Uplink Frequency Band	Downlink Frequency Band
1	I + VIII (2100 MHz + 900 MHz)	I or VIII	I and VIII
2	II + IV (1900 MHz + AWS)	II or IV	II and IV
3	I + V (2100 MHz + 850 MHz)	I or V	I and V
4	I + XI (2100 MHz + 1500 MHz)	I or XI	I and XI
5	II + V (1900 MHz + 850 MHz)	II or V	II and V

Figure 3 Dual Band HSPA Configuration [3] [4].

II. LINK IMBALANCE

The Link Imbalance method technique is actually used to analyze Uplink and Downlink instability on a Heterogeneous Network where generally the Heterogeneous Network has two types of transmitters namely low power and high power transmitters. A simple illustration of Link Imbalance Heterogeneous Network can be seen in Figure 4 below.

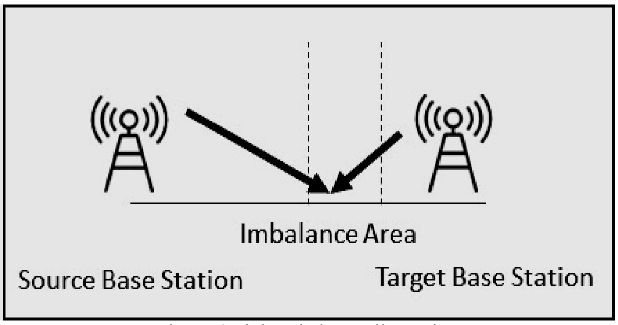

Figure 4 Link Imbalance Illustration

And refer to [5] [6] [7] Link Imbalance calculation is denoted as below:

Imbalance = (Ptx A – Ptx B) + (Nrx A – Nrx B) (1)

where:

PTxA = Transmit Power in Point A (CPICH Power) [dB]
PTxB = Transmit Power in Point B (CPICH Power) [dB]
NRxA = Receiver Sensitivity in Point A [dB]
NRxB = Receiver Sensitivity in Point B [dB]

In [5] assume that the formulation (3) for the uplink load value is the same for Site A and Site B (Site used for reference). In fact the load uplink value is different for all sites. Whereas according to [6] imbalance can be calculated as follows:

Imbalance=(IDLA+IULA)-(IDLB+IULB) (2)

Where detail and focused calculation in Downlink side

$$I_{DLN} = P_{TxN} + G_{DLN} - L_{DLN} + G_{UE} \quad [\text{dB}] \qquad (3)$$

We can refer N to represent for Point A and Point B), and also in uplink side:

$$I_{ULN} = P_{TxUE} + G_{UE} - L_{ULN} + G_{ULN} + G_{DIV} - N_t - N_{RXN} - ROT + G_{eq} \quad [\text{dB}] \qquad (4)$$

Where:
IDLN = Imbalance in Downlink
IDLN = Imbalance in Uplink
PTXN = CPICH Power N (CPICH Power) [dB]
GDLN = Gain antenna N in Downlink [dB]
LDLN = Path Loss in Downlink [dB]
GUE = Gain antenna in user equipment [dB]
PTXUE = Transmit Power in user equipment [dB]
LULN = Path Loss in Uplink [dB]
LDLN = Path Loss in Downlink [dB]
GULN = Gain antenna N in Uplink [dB]
GDIV = Gain diversity [dB]
Nt = Noise thermal power [dB]
NRXN = Noise Figure [dB]
ROT = Rise Over Thermal [dB]
Geq = Gain equalizer [dB]

If equations (3) and (4) by counting the uplink load only from the actual value of the HSPA network we can get the following equation:

Imbalance = (Ptx A – Ptx B) + (ROT A – ROT B) (5)

And also according to [5] and [6] to reduce the imbalance effect (either + or - which is too large) can use the CIO Offset parameter so that we can still maintain the uplink value even though there is HSPA Dual Band activation.

In this research we also evaluate Link Imbalance by using and modifying it as follows:

- Link Imbalance standard Equation to calculate Transmit Power (Downlink) and Uplink Load (Refer to equation 5),

• Link Imbalance modification 1 Equation to calculate Uplink Load only:

Link Imbalance Modification 1 =

$$(ROT\ A - ROT\ B) \quad (6)$$

• Formula Link Imbalance modification 2 to calculate Uplink Load and CIO Offset:

Imbalance Modification 2 =

$$(ROT\ A - ROT\ B) + (CIO\ Offset\ A\ to\ B - CIO\ Offset\ B\ to\ A) \quad (7)$$

III. FUZZY LOGIC

According to [8] fuzzy logic is one of the constituent components of soft computing. Fuzzy logic was first introduced by prof. Lotfi A.zadeh in 1965. The basis of fuzzy logic is the fuzzy set theory. And the reason for using fuzzy logic is as follows:

• The concept of fuzzy logic is easy to understand
• Fuzzy logic is very flexible
• Fuzzy logic has tolerance for incorrect data
• Fuzzy logic is able to model a very complex non-linear function function

According to [9] [10] [12] it can also be used for traffic balancing and as a method of decision making using certain flexible parameters, as a reference structure of fuzzy logic can be seen in Figure 5.

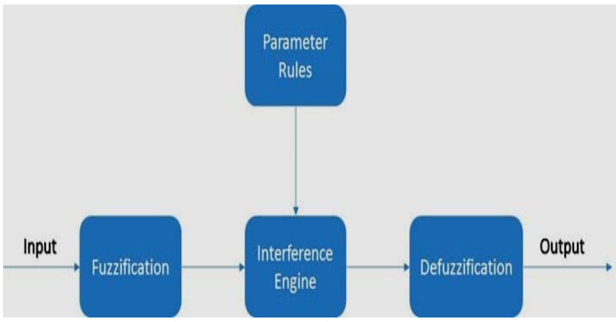

Figure 5 Fuzzy Logic Structure [12]

Parameter Input for fuzzy logic controller data refer to [9],[11],[12],[13],[14].

• Target uplink load: To evaluate neighbor candidate current and available uplink load,

• Distance Between Source and Target Cell / Base Station: Distance measurement / metric effective to evaluate load balancing decision,

• Number of soft handover attempt: To evaluate whether the source and target cell number of soft handover attempt, which more frequent attempt can be possible to be target load balancing.

And for parameter rules / defintion / threshold which will be applied in fuzzy logic see Table I below.

For this research we propose several solution / alternative to be input in fuzzy logic strucutre as decision making support, solution mapping can refer to Table II.

TABLE I. FUZZY LOGIC PARAMETER RULES

Fuzzy Logic Parameter	Variable	Linguistic Definition
Imbalance Basic Formula	<6 - Low 6-9 Medium >9 High	<6 - First Priority to Load Balance 6-9 Second Priority to Load Balance >9 Third Priority to Load Balance
Imbalance Modified Formula 1	<6 - Low 6-9 Medium >9 High	<6 - First Priority to Load Balance 6-9 Second Priority to Load Balance >9 Third Priority to Load Balance
Imbalance Modified Formula 2	<6 - Low 6-9 Medium >9 High	<6 - First Priority to Load Balance 6-9 Second Priority to Load Balance >9 Third Priority to Load Balance
Target Uplink Load	<60% - Low 60%-80% - Medium >80% - High	<60% - First Priority to Load Balance 60%-80% - Second Priority to Load Balance >80% - Third Priority to Load Balance
Distance	<1.5 - Low 1-5 - 3 Medium >3 High	<1.5 - First Priority to Load Balance 1-5 - 3 Second Priority to Load Balance >3 Third Priority to Load Balance
SHO Attempt	> 1000 - High 500 - 1000 - Medium < 500 Low	> 1000 - First Priority to Load Balance 500 - 1000 - Second Priority to Load Balance < 500 Third Priority to Load Balance

TABLE II. SOLUTION FOR FUZZY LOGIC INPUT

Solution Name	Definition	Fuzzy Logic Input
Solution A	Uplink Load Percentage after DB HSPA Profile and using Fuzzy logic for load balancing	- Imbalance Basic Formula - Target Uplink Load - Distance
Solution B	Uplink Load Percentage after DB HSPA Profile and using Fuzzy logic for load balancing	- Imbalance Modified Formula 1 - Target Uplink Load - Distance
Solution C	Uplink Load Percentage after DB HSPA Profile and using Fuzzy logic for load balancing	- Imbalance Modified Formula 2 - Target Uplink Load - Distance
Solution D	Uplink Load Percentage after DB HSPA Profile and using Fuzzy logic for load balancing	- Imbalance Basic Formula - Target Uplink Load - SHO Attempt
Solution E	Uplink Load Percentage after DB HSPA Profile and using Fuzzy logic for load balancing	- Imbalance Modified Formula 1 - Target Uplink Load - SHO Attempt
Solution F	Uplink Load Percentage after DB HSPA Profile and using Fuzzy logic for load balancing	- Imbalance Modified Formula 2 - Target Uplink Load - SHO Attempt
Solution G	Uplink Load Percentage after DB HSPA Profile and using Fuzzy logic for load balancing	- Imbalance Basic Formula - Distance - SHO Attempt
Solution H	Uplink Load Percentage after DB HSPA Profile and using Fuzzy logic for load balancing	- Imbalance Modified Formula 1 - Distance - SHO Attempt
Solution I	Uplink Load Percentage after DB HSPA Profile and using Fuzzy logic for load balancing	- Imbalance Modified Formula 2 - Distance - SHO Attempt

In general, a simple formulation of fuzzy logic is the creation of a membership degree that is simply translated as follows:

$$\mu_A(x) = 1 \quad (8)$$

$$\mu_A(x) = 0 \quad (9)$$

$$\mu_A(x) = \mu,\ when\ 0 < \mu < 1 \quad (10)$$

That is where (8) is a full member of set A, (9) is not a member of set A while (10) is a member of set A with a membership degree of μ

For fuzzy Logic Basic Operator, defined as below:

$$\text{AND Operator} = \mu_{A\cap B} = \min(\mu_A(x), \mu_B(y)) \quad (11)$$

OR Operator = $\mu_{A \cup B} = \max(\mu_A(x), \mu_B(y))$ (12)

NOT Operator = $\mu_{A'} = 1 - \mu_A(x)$ (13)

IV. LOAD BALANCING

Load Balancing become one of solution to perform traffic share in intra or inter system [15]. In this research we are using Horizontal Load Balancing process, which mean load balancing process happened in intra system in example 3G to 3G or 4G to 4G system, usually there are two main load balancing type : Horizontal Load Balancing and Vertical Load Balancing, detail type can be describe as figure 6.

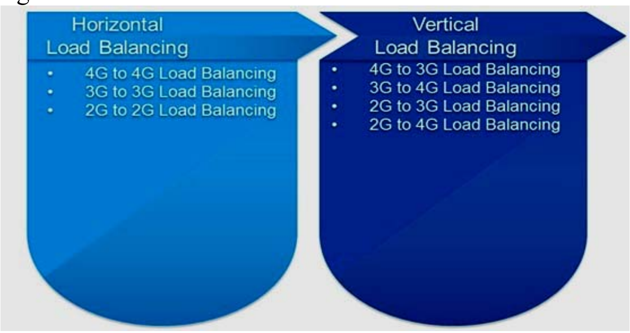

Figure 6 Load Balancing type [15]

In this research also we define transfer load process / load balancing process refer to [16], [17], user sharing in soft handover process can be denoted as below:

Load factor = $\frac{1}{Active\ Set} * Uplink\ Load\ Source$ (15)

Load transfer process between cells with high uplink load transfer to selected neighbor cell with fuzzy logic decision making result, then source cells will reduce with load factor number and automatically the target cell will be add with load factor cells.

V. THE DESIGN PROCESS

One method of Load Balancing is the addition and subtraction of CIO Offset, and in this study the reference point or basic reference for conducting traffic steering with CIO Offset is by calculating the imbalance link. In general, [5] [6] the calculation of imbalance links on multi carrier or multi layer more takes into account the transmit power factor of base station or downlink side only, whereas with the activation of Dual Band HSPA uplink factor must be taken into account [3] and also basically a WCDMA network is a network whose capacity is limited to the uplink side [16] [17].

The calculation of imbalance or imbalance link will be highly correlated as the initial data and reference Load Balancing, and where in general the previous research of imbalance link count only focused on the downlink only [5] [6] where in fact the uplink factor is the determinant of WCDMA-HSPA capacity or balance or imbalance of a reference point for traffic steering.

In this study the results of the link imbalance will be calculated where the uplink load factor from the actual value that will be calculated so that the Dual Band HSPA implementation will be very effective and also the most basic step so that the implementation and activation of Dual Band HSPA will be more optimal and guaranteed, for design process system can be seen as figure 7.

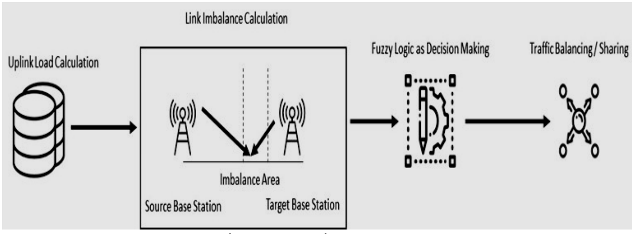

Figure 7 Design Process

Parameter input and solution which define in fuzzy logic process can be described as Figure 8.

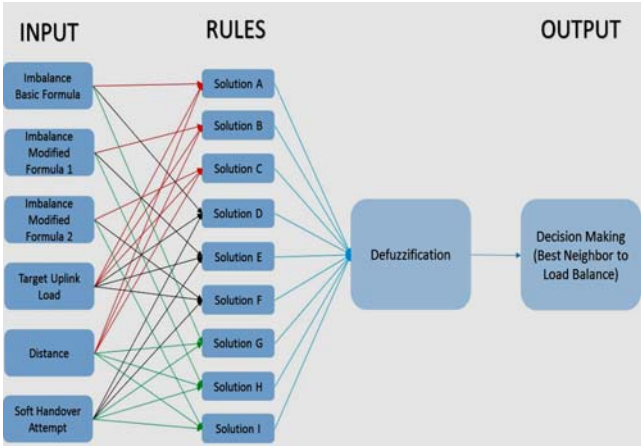

Figure 8 Design Process in Fuzzy Logic Part

The details of the design process between link and fuzzy logic can be described in Algorithm1 below.

Algorithm 1: Load balancing design process

Require: Network Data configuration and performance

1. Collect measurement from network performance : Uplink Load Data and Soft Handover attempt
2. Collect data configuration : Distance, Neighbor list and CPICH Power
3. Calculate Link Imbalance for all method
4. Fuzzy Logic Process with Solution A until Solution I
5. Decision making based on fuzzy logic result
6. Load balancing and traffic sharing from source cell to target cell based on decision making

VI. SIMULATION AND RESULTS

We used 3 methods to evaluate the link imbalance: i) Standard Link Imbalance, ii) Imbalance Modified Formula-1, which considers only uplink side, iii) Imbalance Modified Formula-2, which considers uplink side and handover offset. No significant difference was found between these 3 methods.

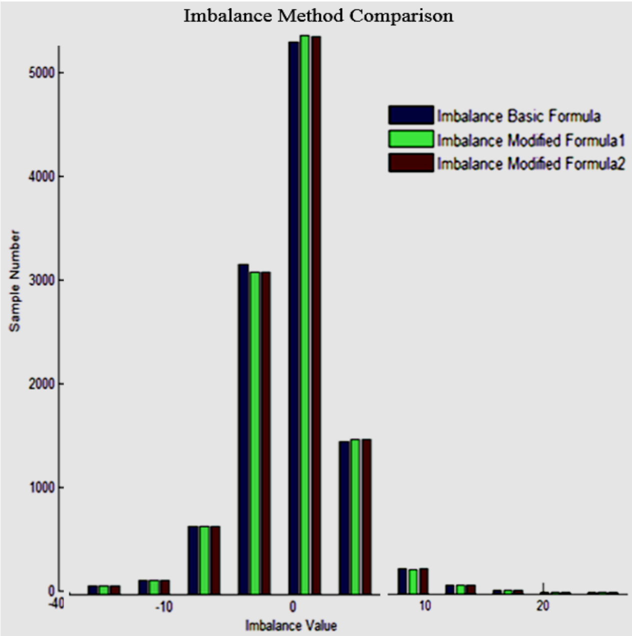

Figure 9. Link Imbalance Method in Histogram

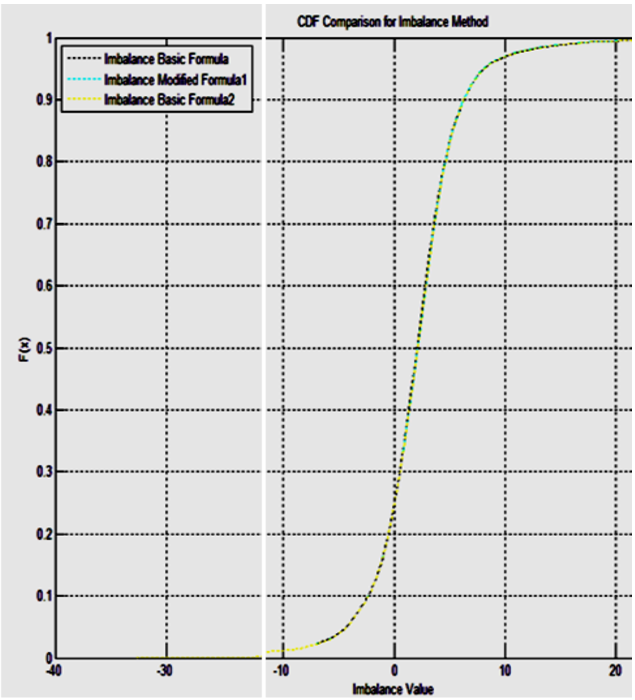

Figure 10 Link Imbalance Method in CDF.

As shown in figure 9 in histogram comparison, very little difference could be detected between the imbalance methods. Based on CDF analysis for the 3 methods shown in Figure 10, very little difference between CDF 3 Imbalance methods.

For load balancing process in this research we used link imbalance and fuzzy logic for decision making. In the data parameter input we used a different solution (from solution A to solution I) to evaluate the final result, which is given in table III below.

And based on statistic data after load balancing, as can be seen table III below, which also summarizes for actual condition, after DB HSPA Activation and Solution A until Solution I, based on table III below we can state that Solution G is the best solution based on mean and standard deviation value.

TABLE III. STATISTIC DATA SUMMARY

Scenario	Mean	Standard Deviation	Variance
Actual Condition	68.4953	19.17753238	367.7777
Average UL Power Util + Increment 5%	72.11478	19.42684589	377.4023
Solution A	65.64296	14.50919363	210.5167
Solution B	65.51305	14.47184674	209.4343
Solution C	65.65574	14.71414835	216.5062
Solution D	65.17685	14.9277007	222.8362
Solution E	65.15677	15.31697218	234.6096
Solution F	65.11553	15.21048445	231.3588
Solution G	64.7336	14.79951062	219.0255
Solution H	64.73585	14.80221425	219.1055
Solution I	64.7762	14.80250226	219.1141

For Result in Histogram Result in figure 11 below, uplink load percentage shift from 70%-90% load distribution to 50%-70% load distribution.

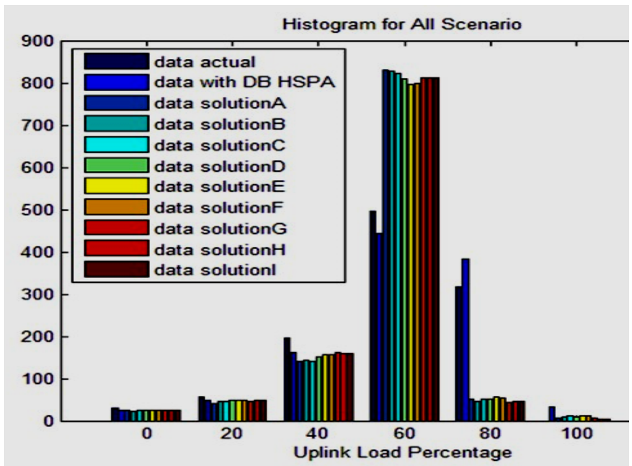

Figure 11 Histogram For All Load Balancing Scenario

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For final result in Normal Distribution, we can refer to Figure 12 below, PDF mean shifting from around 68% until 72% to around 64% uplink load percentage For final result in PDF, we can refer to Figure 12 So this load balancing result from PDF analysis can indicate that load balancing from traffic sharing simulation is success.

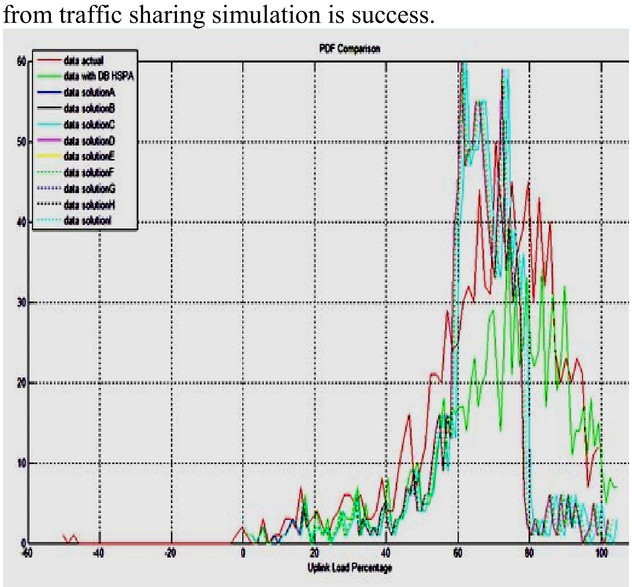

Figure 12 PDF for all Scenario.

While also for CDF analysis in for all scenario (include actual Data and data with Dual Band HSPA Activation also solution A until solution I) 95% data sample has been shifting from 94% - 98 % data sample shift to 79 % - 86 % data sample. As per describe in Figure 13, so from this CDF analysis can indicate that load balancing simulation is success.

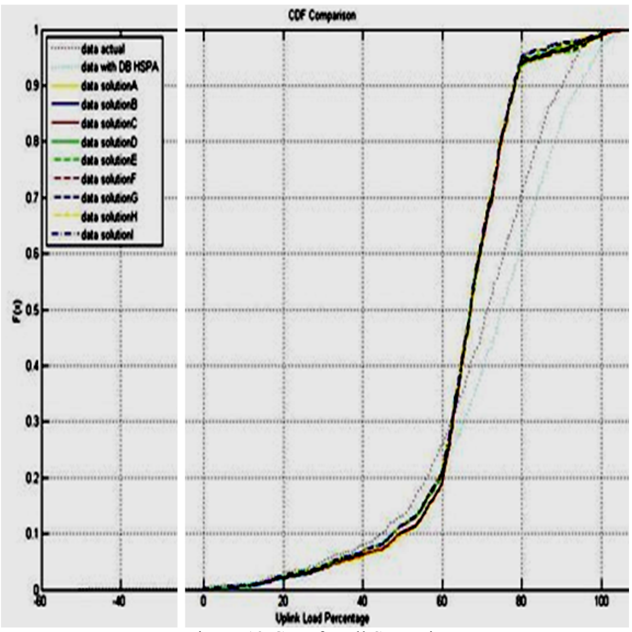

Figure 13 CDF for all Scenario

VII. CONCLUSION

For Link imbalance, no significant change was found between the 3 methods evaluated.

From data statistics summary we can conclude that Solution G (Imbalance basic formula, Distance and Soft Handover attempt) is the best method as fuzzy logic input has the lowest mean value and standard deviation compared to the other solutions.

From Histogram analysis, using load balancing simulation, can move the uplink load percentage shift from 70% - 90% load distribution to 50% - 70% load distribution.

From CDF analysis, using load balancing simulation, we can shift the normal distribution from around 90% to 80 % load in 95 % CDF data sample.

Future work is related to traffic sharing, to conduct comparative evaluation with other methods such as Markov analysis to evaluate the load balancing results.

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