International Journal of Information and Communication Technology Research

http://www.esjournals.org

Evaluation and Optimization of Quality of Service (QoS) of Mobile Cellular Networks in Nigeria

Alexander .N Ndife[1], Anthony .U Okolibe[2], Emmanuel .O Ifesinachi[3], Davies .K Nnanna[4]

[1] Electronic and Computer Engineering Dept., Nnamdi Azikiwe University, Awka

[2, 4] Computer Warehouse Limited (CWL), Lagos

[3] Electronic Development Institute (ELDI), Awka.

ABSTRACT

Evaluation and Optimization of Quality of Service (QoS) of Mobile Cellular Networks was embarked on as a result of incessant complaints of substandard services by GSM users in Nigeria. It was carried out using a Drive Test aimed to access the live network over an air interface in Nigeria. Five KPIs was used as the metrics for the evaluation which includes: Call Setup Success Rate (CSSR), Call Completion Rate (CCR), Call Drop Rate (CDR), Call Handover Success Rate (CHSR) and Standalone Dedicated Control Channel (SDCCH). Data collated from these KPIs was analyzed against the regulators threshold levels. Chi-Square Test was later used to determine whether the KPI values collated differ significantly with the regulators threshold. However, the performance of these KPIs across the Networks was unfortunately found to be below standard with 30% deviation with respect to the regulators threshold levels especially on the CHSR during the Month of March, 2012, though the validation test carried out on April, 2012 showed 25% deviation. Hence, a holistic Network Optimization was carried out using an Adaptive Network-Based Fuzzy Inference System (ANFIS) Model. This was done to boost the performance of the KPIs to the expected level that could guarantee a better Quality of Service.

Keywords: Quality of Service (QoS), Key performance Indicators (KPI), Optimization, Base Transceiver Station (BTS), and Thresholds.

1. INTRODUCTION

Objective measurement of service quality in mobile cellular networks has being very difficult to key players in the industry because of the divergence of views. Some adjudge quality based on reliability, security, assurance, simplicity and flexibility of the network, others focused on coverage, rewards and offering of incentives, prices of service and billing etc. Quality of Service is defined by **ITU-T** recommendation **E.800** as: the collective effort of service performance, which determines the degree of satisfaction of a user of the service. International Organization for Standardization **ISO 9000** defines Quality as the "degree to which a set of inherent characteristics fulfils requirements" [1]. However, the distinguishing characteristics for QoS from these definitions tend towards two major ends: a credible and reliable assessment of the likelihood that users will find the service satisfactory; and the determination on how system performance could be changed when that assessment shows that users are not likely to be satisfied [2].

QoS challenges in Nigerian communications industry could be likened to rapid expansion (rising from about 400,000 active lines as at 2001 to over 105 million active lines as at October, 2012 with teledensity of 78.21) without corresponding Network infrastructures [3]. As the number of users' increases with emergence of various real-time applications, inability to set up calls, abrupt calls drops, occasional service outages, cross-talks and network congestions among others became imminent. This problem has been criticized by both industry and consumer groups among other stakeholders. In finding solutions to the problem, the body responsible for the regulation of Communication in Nigeria, issued out threshold levels on some Key Performance Indicators. This study would be limited to the Five (5) KPIs: Call Completion Rate (CCR), Call Setup Success Rate (CSSR), Call Drop Rate (CDR), Call Handover Success Rate (CHSR) and Standalone Dedicated Control Channel (SDCCH) for objectivity of the measurement [3]. These indicators cut across the standard metrics for mobile phone quality of service assessment such as Network Accessibility, Service Accessibility, Service Integrity, and Service Retainability.

This work is structured into three stages, the data collection stage; data analysis stage and data optimization stage. The result of this study would help Network Operators define and evaluate its successfulness towards its long-time organizational goals. It would also spur the regulatory body to consolidate its effort towards developing a more robust framework for rapid telecommunications growth.

2. RECENT QOS RESEARCH EFFORTS IN NIGERIA

This research [4] was mandated by NCC on July, 2007 to carry out an independent survey on the Mobile Networks. It used probability sampling method to collect data from GSM telephone subscribers. The respondents were users of Mobile (GSM) telephone, aged at least 18years. The data samples size evaluated was 20,000 structured questionnaire and interviews administered to GSM users across some selected states in the six geo-political zones in Nigeria (i.e. Enugu, Port Harcourt, Kano, Sokoto, Lagos, and Abuja). At the end of the survey, the result showed that the services rendered to the subscribers were generally poor especially in the areas of tariff, abrupt call drop and delay in SMS delivery.

Most recently is [5] carried out by an independent researcher using three (3) handsets in placing calls at different locations (Lagos, Port Harcourt and Abuja) for a period of six consecutive days, to determine the level of congestion in the network. This is a real-time survey setting up 72,334 calls over the period of study. Mobility management as regards to seamless handover from one cell to another was not accounted for with this methodology. The results also concluded that the QoS in the country was very poor especially on some networks due to congestion.

3. RESEARCH METHODOLOGY

This research work is divided into three major stages: the first was the data collection part; the second one was the analysis part and finally the optimization part. The measurement tool used for Data collection is QVOICE equipment. This statistical monitoring equipment was used to acquire the data over a live network; thereafter transfer it for post-processing via SQL-Server. A special made cell phone Nokia (6230i) was used as trace Mobile designating the four Mobile Operators in Nigeria (MTN, GLO, ETISALAT and AIRTEL). Its channels consist of uplink and downlink paths corresponding to Master and Slave. The call configuration was made to be intra-network between the master channel and its slave. After the measurement data collated was imported into QVP part for proper analysis and subsequent evaluation [6].

3.1 Research Design

Drive test was carried out in F.C.T Abuja during the morning, afternoon and evening session from 12-18 March, 2012. During analysis peak hour of the day was considered. Federal Capital Territory has an area of 713km squares with a population of 776,298 active subscribers according to data samples analyzed. It is an urban area made up of mid-range and few tall buildings. Its day-time temperature fluctuates between 28°C to 32°C, while night-time ranges from 22°C to 23°C. It has high altitude and undulating terrain. Five KPIs stated earlier were chosen as independent variables. These KPIs was collected from the live network over an air interface randomly. They were grouped into strata with each stratum representing a particular key performance indicator. These samples represented the activities of Base Transceiver Stations and its corresponding Base Station Controller supervising it as it were observed within 30 minutes interval. A conceptualized Optimization technique using Adaptive Network-Based Fuzzy Inference System (ANFIS) model was developed to boost the KPI dataset.

4. PROCEDURE FOR DATA COLLECTION

The sample measurements were generated from the networks as earlier mentioned via an air interface, which was later transferred from the QVM into QVP for analysis using file transfer tools of the system. The call statistics data like failed or dropped calls, handover complete/failure for intra-cells, seizure success or failures, channel requests; etc was used to determine values for the KPIs studied. The MapInfo of the QVM enables the mapping of the areas of survey or routes which was saved in the database. During the drive test, activities of BTSs, BSCs, and MSCs along the mapped routes were recorded and areas where congestions occurred noted.

4.1 Data Post-Processing Stage

From the QVM (Monitoring equipment) the data collected was transferred to QVP (post-processing equipment) for analysis. A database was created, and data collected was imported into this database where data of no interest was filtered. The evaluation was done by querying the relational database using Structured Query Language (SQL) command. This analysis was done over a period of one week. The KPI data collated were grouped into strata on hourly basis against individual operators as shown in Table 1. The graphs were illustrated in Fig 1 & 2.

Table 1: Analyzed KPI data set.

KPI data for March, 2012					
Name of operators	CSSR (Target ≥ 98%)	CDR (Target ≤ 2%)	CCR (Target ≥ 96%)	CHSR (Target ≥ 98%)	SDCCH (Target ≤ 0.2%)
MTN	97.07	1.33	96	95.14	0.58
GLO	97.33	1.13	96.44	97.73	0.39
ETISALAT	94.38	0.86	93.05	89.67	1.64
AIRTEL	97.39	0.86	96.56	96.64	0.58
KPI data for April , 2012					
Name of operators	CSSR (Target ≥ 98%)	CDR (Target ≤ 2%)	CCR (Target ≥ 96%)	CHSR (Target ≥ 98%)	SDCCH (Target ≤ 0.2%)
MTN	96.42	1.41	95.78	94.67	0.61
GLO	97.02	1.17	96.45	97.67	0.39
ETISALAT	96.88	1.22	95.81	91.28	1.36
AIRTEL	97.48	0.92	96.59	96.33	0.47

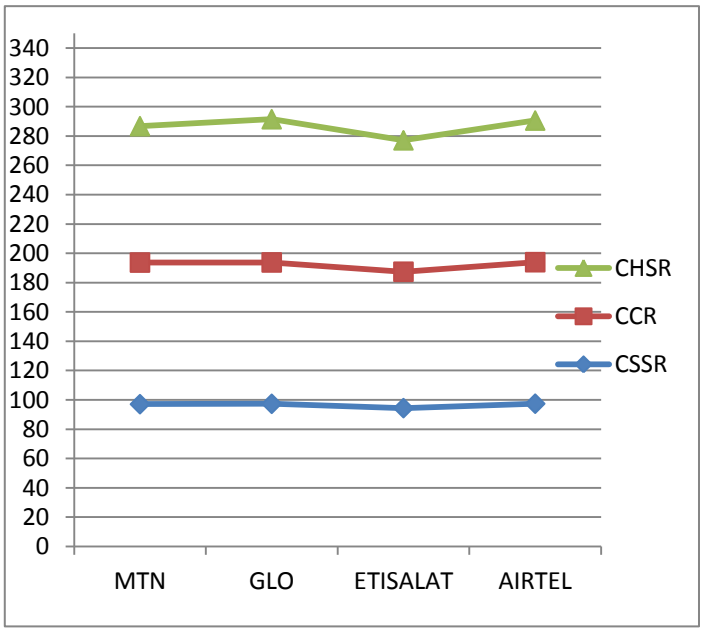
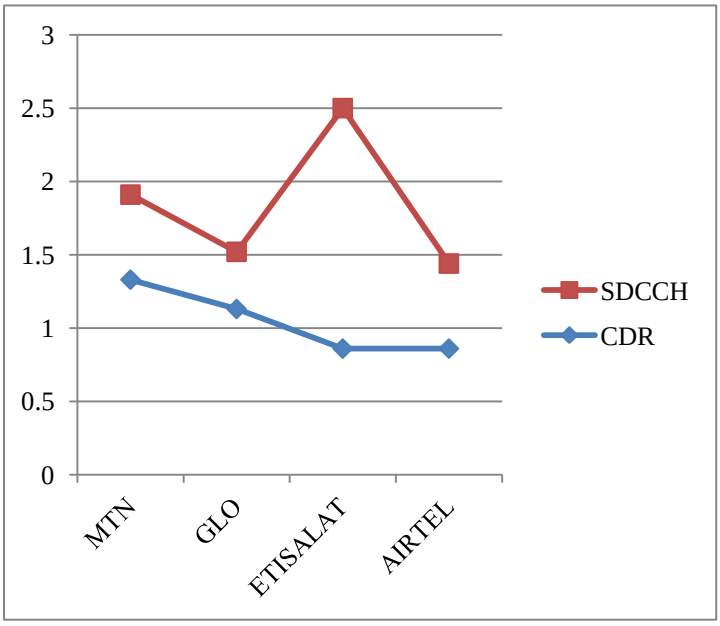


Figure 1 Graph of CSSR, CCR and CHSR across the Operators

Figure 2: Graph of CDR and SDCCH across the Operators



Chi-Test analysis was later carried to obtain the result shown in Table 2 using the formula:

Chi-Test = $\sum \frac{(E-O)^2}{E}$ [7], where **E** is expected value and **O** is observed value.

Hypothesis Testing:

To test the null hypothesis to confirm that each of the five KPI values differed or did not differ significantly from the expected threshold set as target by the regulator.

Table 2: The Results of the Chi-Test Calculation for March, 2012

KPI	Chi-Test Values Per Operator For March, 2012.			
	MTN	GLO	ETISALAT	AIRTEL
CSSR	18.39	15.29	55.38*	14.46
CDR	7.80	11.40	11.40	11.40
CCR	8.99	6.88	85.70*	7.86
CHSR	39.46*	9.35	67.55*	27.17*
SDCCH	10.37	3.92	92.74*	10.37

Table 3: The Results of the Chi-Test Calculation for April, 2012

KPI	Chi-Test Values Per Operator For April, 2012.			
	MTN	GLO	ETISALAT	AIRTEL
CSSR	21.94*	13.65	15.59	7.26
CDR	7.04	9.21	8.79	11.04
CCR	3.68	6.31	2.66	8.29
CHSR	45.83*	4.61	90.85*	23.18*
SDCCH	11.62	3.92	63.34*	6.33

The sample distributions of Table 2 & 3 are approximately distributed as **Chi-Square** on K-1, K is the number of variables (i.e. KPIs) = 5, N is the sample size for all the KPI groups = 7 (i.e. seven days test period).

Degree of Freedom (D.F) within the KPI groups = N-K, i.e. 7-5 = 2.

It implies that Degree of Freedom within KPI groups is 2.

From the statistical table [8], when K=4, and D.F=2, the critical value was found to be 19.2 at 0.05 level of significance.

4.2 Analysis of Chi-Test Result

From Table 1, CSSR values were found to be less than the critical value except for ETISALAT that has 55.38 marked with asterisk. This shows that the observed CSSR values for different operators did not differ significantly from the regulators threshold.

For CDR, values were also less than the critical value. This shows that the observed CDR values for different operators did not differ significantly from the regulators threshold.

For CCR, values were less than the critical value of 19.2 except for ETISALAT that has 85.70 marked with asterisk. This shows that the observed CCR values for different operators did not differ significantly from the regulators threshold.

For CHSR, values were greater than the critical value of 19.2 except for GLO that has 9.35. This result shows that the observed CHSR values for different operators differ significantly from the regulators threshold.

For SDCCH, values were less than the critical value of 19.2 except for ETISALAT that has 92.74 marked with asterisk. This shows that the observed SDCCH values for different operators did not differ significantly from the regulators threshold.

The overall result shows that 30% of the KPIs studied are below regulators threshold with **ETISALAT** accounting for 20%. Also 15% of the degradation was recorded in **CHSR**. However, 5% improvement was recorded in month of April validation test. Climatic factors influence in the result of the survey may not be excluded.

4.3 Optimization of the KPI Dataset

A conceptualized optimization technique was developed to boost the dataset using Adaptive Network Based Fuzzy Inference System model developed by Roger Jang [9], as a scientific solution in lieu of physical solutions like: addition of

more BTS (where there is limited coverage), BTS restart/reselect hysteresis & antenna adjustment or tilting (where it isn't functioning optimally). However, this optimization tool performs input-output mapping of the KPI dataset by computing the membership functions parameters that allows Fuzzy Inference System (FIS) to track the given input/output data using a combination of least square estimation and back propagation or gradient method. These membership functions parameters changes during data learning process until gradient vector is obtained. From the Algorithm of Appendix 1, once the gradient vector (i.e. the variation between actual output and desired output) is obtained and added to the actual data, optimization is done.

4.4 Data Training Process

In order to realize the model represented in Fig 3, MATLAB fuzzy neural inference engine was employed by creating the five logical KPI channels in a Sugeno-Takagi FIS while creating the required membership variables as shown in figure 4. The KPI and Sugeno-Takagi engine are set while calling the MATLAB ANFIS function so as to load data, train and generate the FIS. The function *fuzexltrnData* loads the dataset for training in the workspace by adjusting the membership function parameters that best model the data using *fuzexlchkData*. The command *genfis1* generates a single-output FIS which is used to provide initial condition ANFIS data training.

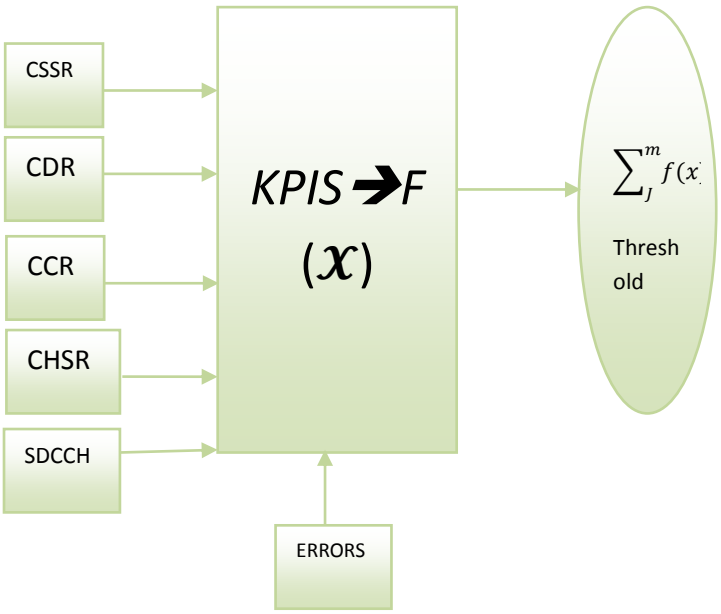


Figure 3 Fuzzy Neural Optimization Scheme

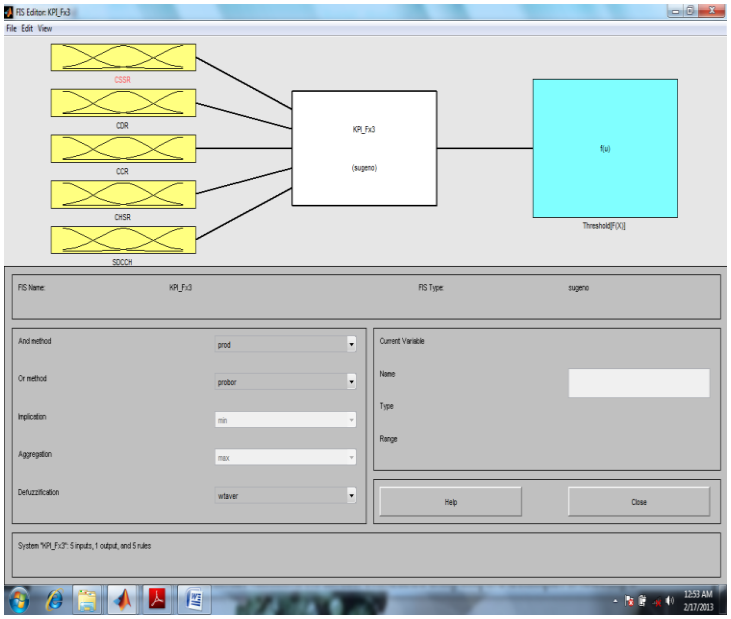


Figure 4: Sugeno-Takagi KPI Optimization setup

The training data which was obtained from the drive test is comprised of CSSR, CDR, CCR, CHSR and SDCCH. Partitioning the data in the MATLAB work space saved as *kpi*, this was loaded for training in the neural platform. After the KPI training and generation of FIS, an offset rule viewer for the KPI is realized as shown in Fig 6.

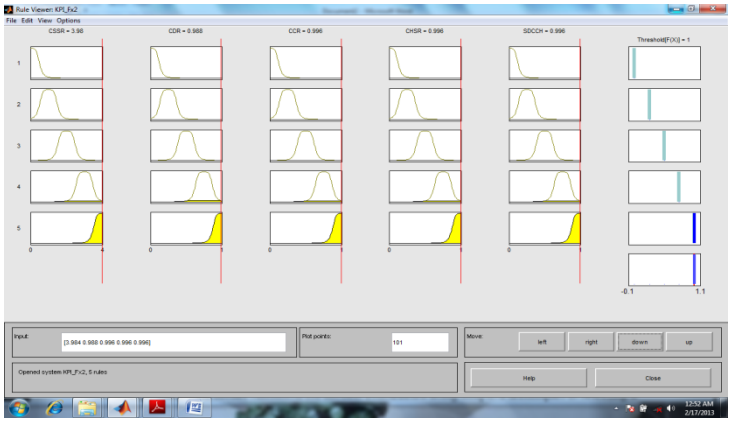


Figure 6: An Offset rule viewer for KPI optimization algorithm.

The combination of parameter adjustments and rule base simplification resulted to the Optimization and its normalization. During the optimization, the function output is added to the offset value which is then added to the KPI values. During the normalization, the algorithm developed checks and matches the KPI values. Truncation is done when the optimized KPI value exceeds the recommended thresholds. Also, when the KPI values are in exact ranges, the algorithm adjusts for the KPI values.

Table 2: Optimized KPI Data set

KPI data for March, 2012					
Name of operators	CSSR	CDR	CCR	CHSR	SDCCH
MTN	102.054	1.330	97.996	98.000	0.58
GLO	102.314	1.130	98.436	99.726	0.39
ETISALAT	99.364	0.848	95.046	98.000	0.64
AIRTEL	102.374	0.848	98.556	98.636	0.58
KPI data for April , 2012					
Name of operators	CSSR	CDR	CCR	CHSR	SDCCH
MTN	101.404	1.41	97.776	96.666	0.61
GLO	102.004	1.17	98.446	99.666	0.39
ETISALAT	101.864	1.22	97.806	98.276	0.39
AIRTEL	102.464	0.92	98.586	98.326	0.47

With this result, it proves that optimization is feasible in real cellular network operating on 3G network.

5. CONCLUSION AND RECOMMENDATIONS

This study evaluated Mobile Cellular Networks Quality of Service performance in Nigerian context based on five KPIs selected and benchmarked against the regulators thresholds. **Chi-Test** analysis was used to determine the degree of deviation of the KPIs from regulators threshold. The result showed 30% variation in which 15% was recorded in CHSR. Hence, optimization was carried out using Adaptive Network-Based Fuzzy Inference System model to boost the KPI dataset. This result proves that optimization is feasible in real cellular network. Call handover failure could be cause by any or all of the following: interference, location area boundary wrongly planned or defined, and coverage limitations [10]. Hence Network Operators are thereby advised to review their networks and effect some optimization measures like adjustment of the interference free band; perform adjacencies audit; BSS resources addition (such as TRX); modification of handover margin and power budget parameter to assist better cell handover.

REFERENCES

[1]. International Telecommunications Union- Telephony (2013) "Quality of Service Definitions", website http:/www.itu.int.

[2]. W.C Hardy, "Measurement & Evaluation of Telecommunications QoS" John Wiley & Sons Limited, USA, pp 1-14, 2001.

[3]. Nigerian Communications Commission (2012); "Quality of service Regulation", website http:/www.ncc.gov.ng

[4]. Decision Consult Limited "GSM Quality of Service Evaluation survey: The Verdict", Nigerian communications commission (NCC), 2007.

[5]. Prof Augustine Odinma, (2011) "The Problem of Congestion in Mobile Networks in Nigeria" http:/www.itrealms.com.ng.

[6]. Peter Beiner, "User Manual QVOICE" Ascom (schweiz) AG, May 3rd, 2005.

[7]. MSTE (2013) "Chi-Square", http://www.mste.uiuc.edu/patel/chisquare.html

[8]. M. Merrington "Table of percentage points of the inverted beta (F) Distribution" Biometrika Trustees Vol. 33, pp. 73, 1943.

[9]. Jyh-Shing Roger Jang, "Adaptive Network-Based Fuzzy Inference System" IEEE, Trans. on systems MAN & Cybernetics Vol.23, No.3, May/June 1993.

[10]. T.S Rappaport, "Wireless Communications Principle" Prentice Hall, pp 32- 42, 1997.

Authors' Profile

Ndife Alexander Nnamdi is currently a research student in Electronic and Computer Department of Nnamdi Azikiwe University, Awka, Nigeria with research interest in wireless communication and digital signal processing. He also holds M.Eng. in Communication Engineering from the department.

Okolibe A. U is currently in Computer Warehouse Limited, Lagos, Nigeria. He holds B.Eng. and M.Eng. in Communication Engineering from Electronic and Computer Engineering department of Nnamdi Azikiwe University, Awka, Nigeria.

Ifesinachi E. O works in Electronic Development Institute, Awka, Nigeria. He also holds B.Eng. and M.Eng. in Communication Engineering from Electronic and Computer Engineering department of Nnamdi Azikiwe University, Awka, Nigeria.

Nnanna D. K also works in Computer Warehouse Limited, Lagos, Nigeria. He holds M.Eng. in Communication Engineering from Electronic and Computer Engineering department of Nnamdi Azikiwe University, Awka, Nigeria. E-mail:

APPENDIX 1

KPI Optimization/Normalization Algorithm on Fuzzy Neural Processor

Input$_1$:*CSSR;CDR;CCR;CHSR;SDCCH*

Output$_1$.*F(x);Kpi_Opt;*

Begin ()

Set $kpi_{1=98;}kpi_{2=2;}$ $kpi_{3=96;}$ $kpi_{4=98;}$ $kpi_{5=0.2;}$

Set FIS_Engine= KPI_FX2

Call ANFIS ();

Load data Kpi

Generate FIS

Train Kpi FIS

While (data forwarding into Engine) do

Generate FIS rule (Kpi_1 to $_N$)

Compute Offsets{CSSR;CDR;CCR;CHSR;SDCCH; F(x)}

$L_{1:}$ $KPI_1' = ([offset\_CSSR + f(x)] + CSSR)$

$L_{2:}$ $KPI_2' = ([offset\_CDR + f(x)] + CDR)$

$L_{3:}$ $KPI_3' = ([offset\_CCR + f(x)] + CCR)$

$L_{4:}$ $KPI_4' = ([offset\_CHSR + f(x)] + CHSR)$

$L_{5:}$ $KPI_5' = ([offset\_SDCCH + f(x)] + SDCCH)$

If $(KPI_1' \leq kpi_1)$ ***Then***$Kpi\_Opt = KPI_1'$

Else

if $(KPI_1 < kpi_1)$***Then***$Kpi\_Opt = L_1$

Return ();

If $(KPI_2' \leq kpi_2)$ ***Then***$Kpi\_Opt = kpi_2$

Else

if $(KPI_2' > kpi_2)$***Then***$Kpi\_Opt = (KPI_2')^T$

Return ();

If $(KPI_3' \geq kpi_3)$ ***Then***$Kpi\_Opt = KPI_3'$

Else

if $(KPI_3' < kpi_3)$***Then***$Kpi\_Opt = L_3$

Return ();

If $(KPI_4' \geq kpi_4)$***Then***$Kpi\_Opt = KPI_4'$

Else

if $(KPI_4' < kpi_4)$***Then***$Kpi\_Opt = L_4$

Return ();

If $(KPI_5' \leq kpi_5)$ ***Then***$Kpi\_Opt = kpi_5$

Else

if $(KPI_5' > kpi_5)$***Then***$Kpi\_Opt = (KPI_5')^T$

End if

End if

End if End if

End if