Self-Healing in LTE networks with unsupervised learning techniques

Rahmani, Javad and Sadeqi, Abolfazl and Ayeh Mensah, Dennis Nii

Department of Digital Electronics, Islamic Azad University, Tehran, Iran, Department of Electrical Engineering, Hadaf University of Sari, Tehran, Iran, School of Computer Science and Engineering, University of Electronic Science and Technology of China, China

24 March 2020

Computational Research Progress in Applied Science & Engineering

ISSN 2423-4591

CRPASE Vol. 06(01), 40-45, March 2020

Self-Healing in LTE Networks with Unsupervised Learning Techniques

Javad Rahmani[a*], Abolfazl Sadeqi[b], Dennis Nii Ayeh Mensah[c]

[a] Department of Digital Electronics, Islamic Azad University, Tehran, Iran
[b] Department of Electrical Engineering, Hadaf University of Sari, Tehran, Iran
[c] School of Computer Science and Engineering, University of Electronic Science and Technology of China, China

Keywords

Self-healing,
SVM,
ADABOOST,
Fuzzy,
Adaptive Root Cause Analysis.

Abstract

Recently the cellular networks are getting more complex in maintenance and network management, and rapidly growing in the number of users so that repairing and maintenance of the system are becoming more challenging and expensive. To solve the problems and maintain the system, operators depend on their experience but by increasing in type and density of the networks, this way will not operate as before. So Self-organizing network (SON) has been used in this study to solve these issues.

1. Introduction

Self-organizing network (SON) is a set of rules and ideas gets inputs produced by mobile networks and creates output depend on the needs. It can add automation to the mobile network and simplify the planning. By adding it to the network, the automation will reduce the cost of maintenance and make it simpler [1, 2], and also it causes an increase, increases in the quality of service [3, 4] and respond to the needs of the users. It is faster and more reliable than old methods [5].

SON consists of three sections: Self-configuration: includes functions for network deployment and configuration of its parameters and automates the planning and deployment of the network.

Self-optimization: functionalities that keep the configuration parameters always working at the optimal level and dynamically recalculated when traffic and network conditions change Self-optimization includes tuning parameters related to a list of neighbour cells, traffic balance, handover, coverage, etc.

Self-healing: focused on functionalities that automate the solution of problems [6, 7], reducing human intervention and minimizing downtime. Self-healing aims at automating network fault troubleshooting and recovery. Self-healing consists of fault detection, root cause analysis (diagnosis), compensation, and fault recovery.

Till now there were no complete solutions in the cellular network about this case so the purpose of this paper is to fill this gap by comparing the methods of self-healing section and their results. And find the best approach. There are seven methods to compare which are SVM – ADABOOST- Adaptive Root Cause - Fuzzy logic-based -RSRP Mechanism- BIG DATA and Genetic FUZZY.

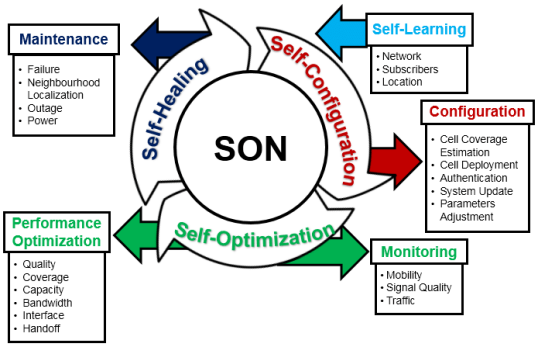

Figure 1. SON algorithm

2. Definition [8, 9]

- Diagnosis Error rate (DER): a ratio of the incorrect diagnosed sample number to the total sample number.
- Undetected rate (UER): a ratio of the error that the system considers them as normal to the sum of the sample.
- False-positive rate (FPR): a ratio of a normal sample that system considers them as faulty to the sum of the sample.
- Reduction of cell power (RP): the transmission power may be decreased because of any possible hardware problem or wrong configuration of parameters.
- Coverage Hole (CH): when the performance of the cell decreases and it has dropped connections and low

* Corresponding Author:
E-mail address: javad.rahmani@srbiau.ac.ir

Received: 21 February 2020; Accepted: 24 March 2020

reliability in an area. It may cause changes in the environment and construction of the building.

- Too Late HO (TLHO): if the edge of the cell service area does not configure well, they users at the edge of the area may have a low quality of connection while they should be connected to another cell with a better quality of connection.
- Inter-system interference (II): In this fault, the configuration is true and users receive a good signal with good coverage area but SINR will affect negatively so connection drop will increase and reliability decrease.
- Excessive up tilt (EU): when a cell has Excessive up tilt, it covers more area than usual. So, the nearby users receive a weaker signal. It depends on antenna radiation patterns.
- Excessive Down tilt (ED): when a cell has a down tilt and the power of the cell focused on an area nearby. So just users nearby get better RSRP levels but the coverage area will reduce.
- Performance management metric (PM): base stations have an array of counters that increase when a special vent happens. Like dropped connection.
- Fault Management Alarms (FM): These faults are some special errors that the reason why they happen is varied (hardware problem or software). There is a binary indicator that the events of this fault are registered in it.
- Configuration Management Parameters (CM): engineers or SON can set each BS configuration. It is a very important parameter because it can show the effect of each event.

3. Methods Definition

3.1. SVM [10]

SVM (support vector machine) used to find the best separating hyperplane in the feature space to divide the samples. The kernel function was used for training sample map from an input space to a high dimensional space, to get the best effect. In this paper, a linear kernel is used [11]. To solve binary classification problems SVM is usable. SVM can only work with binary classification. The decision function of SVM shown Figure 2.

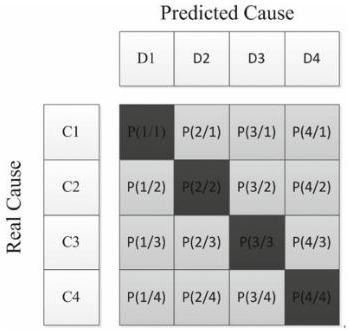

Figure 2. Confusion matrix

SMO (Sequential minimal optimization) is a high-speed Repetitious algorithm and decomposes a large QP (quadratic programming) issues into several minimum size of QP sub issues, and each QP sub issue has two variables so it will train faster.

SVM algorithm define the best decision by finding the largest border between two classes.

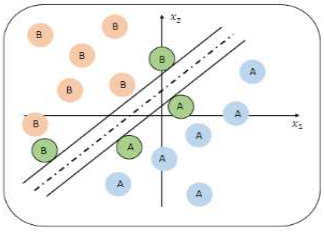

Figure 3. SVM classification

3.2. ADABOOST [10]

ADABOOST (Adaptive Boosting) is one of the learning algorithms and improves the performance of the ensemble classifier in the way that improving the accuracy of the bad classification classifier, after each increasing repetition, the weight will change. According to the classification results, if the classification result is wrong, the weight will be an increase, if not the weight will decrease [12]. In the end, all the classifiers will linearly combine to compose the final classifier [13].

ADABOOST can only work with binary classification. It is a big problem to solve multiclass issues using a binary classifier. One way is to get multi-classification issues and Breakdown them to multiple binary classifications issues and then compose the result of each of them to reach the result. DAG (directed acyclic graph), OAA (one against all) and OAO (one against one) are few ordinary methods of multi-classification based on the binary classifier.

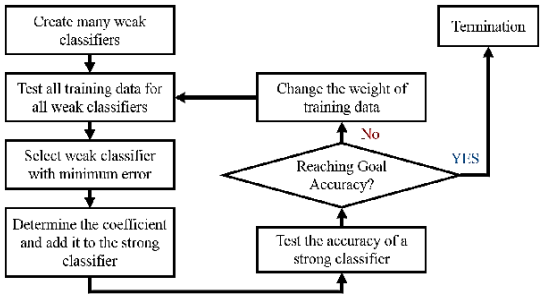

Figure 4. ADABOOST algorithm

3.3. Adaptive Root Cause Analysis (ARCA)

In this method we proposed a solution for automating root cause analysis of cellular network faults based on continuous adaptive learning like a human expert, the developed solution uses continuous adaptive learning for smart decision making. Details about the key components of the solution are present in the next subsection.

3.3.1. Chi-squared Test

Time-dependent statistical profiles are used to capture and present expected values and distribution of monitored cell KPIs and sliding windows concepts to capture the temporal aspect of processing measurement in defined values. The chi-squared test is used for determining the deviations found, if any, between the observed and the expected KPI values captured in the profiles are significantly different.

3.3.2. Naive Bayes Classifier (NBC) Based Diagnosis

NBC is a probabilistic classifier, which is based on Bayes' theorem with a strong (naive) assumption of independence among predictors. There are various of applications for NBC which illustrate its efficiency and effectiveness. NBC is applicable on engineering approaches and problems as predictive model [14]. As a probabilistic model, it is suitable for handling missing or uncertain data and inputs of high dimensions such as cellular network features [15]. Bayes' theorem describes the probability of an event based on conditions and symptoms that might be related to the event. For example, RSRP KPI has directly influenced the coverage of a cell so using NBC an RSRP value can be more accurately assess the probability of an eventual cell coverage problem by exploiting the mathematical probability dependence between the cause and the symptom recorded in the service area.

Pareto analysis-based fault fixing impact ranking: Pareto analysis is a statistical technique used in strategic decision-making processes. It is loosely based on the idea that by doing 20% of the most important work, you can generate 80% of the benefit of doing the entire job. Pareto Analyser component is used in this method to intelligently maximize return on investment by creating a list of top n faults which when fixed, will bring the most value to the network operators and subscribers while taking into account business policies and severity.

3.4. Measurement-based Corrective Action Evaluation

Using the Evaluator, the impact of every corrective action is assessed using all applicable KPIs collected after every fault corrective action. In other words, the evaluation results are used to balance the handling of false positives and false negatives concerning operator goals.

3.5. Fuzzy Logic Based Method [16, 17]

In Fuzzy logic-based Method, KPIs (Key Performance Indicators) are variables inputs, which can be bad or good. It depends on whether if the KPI level is acceptable or not.

On the contrary, the outputs are fault causes which are variables depending on the discrete C. Fuzzy logic is a modeling and control approach in which the system state and actions are classified as belonging to sets and following logical rules based on plain language heuristics and expert knowledge [18]. To represent a Fuzzy logic-based function we use μ symbol. This function defines the value to put the variables into concerned set also in this paper, we use trapezoidal sets because of its simplicity and validity. It has two thresholds: th2: when KPI starts getting bad, th1: KPI consider as Bad. Usually, we consider Ci as the fault cause and (KPI 1 …. KPI) the sets of KPI, that can show if there is a fault or not about the deterioration of the good performance of them. The degree that shows which cells state S is for which Ci is a degree of truth. The diagnosis phase will start when the degree of truth of each possible fault cause has been calculated. To find the fault, the system tries the rules that have the greatest degree. Consider that if there are any not fulfilled rules the degree of all rules will be zero, so the system will not be able to find the fault cause and diagnosis is not recognized.

To test this system simulation in MATLAB created, which include 57 macro-cells, and the antenna pattern, in three simulations.

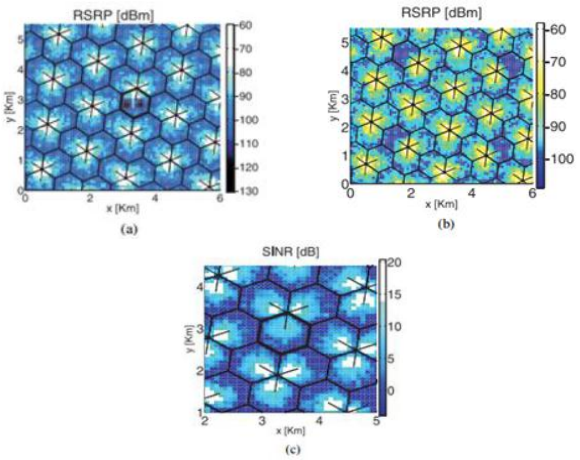

Figure 5. (a) RSRP levels measured by users when there are two coverage holes. (b) RSRP levels measured by users When there are four excessive down tilt. (c) SINR in each point when a system us suffering inter-system interference.

Each cell has the same configuration of a normal cell but randomly some of them show the fault model. In Figure 5(a), the problem is two coverage holes that have lower RSRP than other cells that working in the area. In Figure 5(b), there are four extreme down-tilt cells. These cells cause an area with RSRP less than -100db. In Figure 5(c), there is an inter-system interference so the SINR in this zone is so bad and users cannot experience SINR more than 15dB.

3.6. RSRP Mechanism [19]

RSRP is the first parameter of the LTE network, which refers to (Reference Signal Received Power). This value is the power that users' devices receive. this value is depending on the distance between the user and the site, the more the distance is, the small RSRP receive by user .and users that are too far from the site will not get LTE service, they are out of coverage.

In LTE, the network it is necessary to measure this parameter for detecting the cell outage. In this case, we are using RSRP value measurement that can be read from the UE (user equipment) side. The flowchart of the self-healing mechanism is shown.

RSRP measurement: it will measure from the UE side. The obtained data will be used in the next step.

Cell degradation/outage detection: the process of the data obtained in the RSRP measurement step. If it detects any decrease in RSRP or one of the cells stop sending reports, and then this step will consider it as an outage.

Cell Outage Compensation: In this step, the outage cell's neighbour changes its configuration to compensate network parameters. Also, in this step the stocked and handled information from outage cell and its neighbour will be gathering.

Cell Outage Recovery: This final stage is to minimize the traffic that cannot be served, by way of neighbour-cell helps outage-cell to compensate for traffic that cannot be served. Traffic on outage-cells that are compensated by traffic in these neighbours is called forward traffic.

3.7. Big data [20]

Each part of the cellular network interacts with other parts of the network to establish communications. Every interaction produces events. (Connection establishments, handovers, etc.) Important data of a problem's root cause can save when it happens .and in new cellular networks, these data will save in parts of the network. Diagnose process use data that indicate the state and behaviour of the network. These data are saved in the base station. These base stations have a central database. Some of these data used more than others. BS has gathered these data in a raw format in the form of time series. To use these data easier, they had to convert to readable variables. Special values like dropped connections in a period or ratio of established are measure buy PIs. It has more different timescale like days or hours. PIs represent the general behaviour of parts, so it can be used to better understand them. KPIs have been saved over the category of parts to represent the general behaviour of the network. Not all the PIs are as input data. Some of them created by calculating the data of call traces. The important note is that the data has been gathered physically in network parts but some of these data are about other parts. Such neighbouring BSs. the Figure at the bottom shows their relation.

Blue: raw data, Green: composite data, Red: parts of the network, Orange arrow: process-related

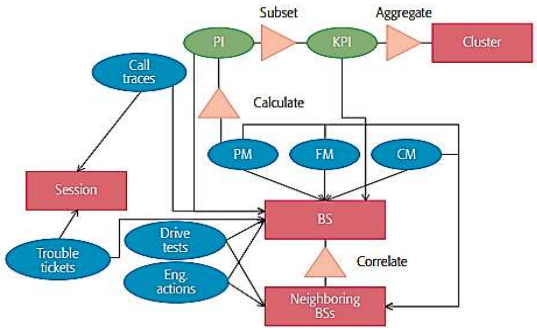

Figure 6. Data types and the relationships established by the information each type contains

3.7.1. Troubleshooting Procedure

These days, the data generated has been increasing very much. Because of the increasing usage of mobile networks and growth in the number of connected electronic devices so, the data and the contained information increase. The data usually is too big and has no structure so it is not possible to react with these data as before. In this situation, we use an algorithm that contains some rules that let us use these data. When a data set follows three rules named three Vs, we can consider it as a bid-data-compliant.

1) Big volume: data quantity is large. The reason may be, first: there is a lot of single and small information unit or a few and large information unit. The value that is a border to be considered as big data depends on application hardware and time constraints.
2) High Velocity: the information produces too fast and it needs special ways to process them before that the new data is produced. The value of the border depends on the hardware and its speed, to process this data as fast as possible to prevent server duration.

3.8. Genetic Fuzzy

Fuzzy logic is used to diagnosis the system by modelling the human thinking process and translating inputs to fuzzy sets and using fuzzy rules. These rules come from operators' flowcharts that they usually use it to troubleshoot the problem. Therefore, the best way to make fuzzy rules is to gather knowledge. The best way is to obtain these rules from solved problems. PIs are values used in mobile networks to observe network behaviour. In manual diagnosis, operators check some of the KPI (key PIs), such as blocked calls, some dropped calls, failed handovers and so on. When a network has degradation in KPIs a list of reasons will be created to find the section that has the degradation. After finding the section or sections, diagnosis goes to the next step and its monitoring addition PIs, configuration audits, and active measurements. In addition, after finding possible cause a repair is applied. If it removes the degradation, the problem will consider as solved. Genetic Fuzzy used in the troubleshooting stage and a set of PIs selected for its input. To limit the thinking process of the operator's fuzzy sets and fuzzy rules are model. It is possible in two paths. First is knowledge acquisition, which the needed rules will set by operators and second is learning algorithm, which the rules will be set by an algorithm from a training set. Genetic Fuzzy uses numerical values and transfer them to descriptive values. It also uses several sets that define over the domain of a crisp variable, which is a common non-fuzzy numerical variable. A fuzzy set includes a value of U that is a characteristic understandable by a human, also fuzzy sets have an associated membership function that shows the truth degree of each crisp value that belongs to fuzzy sets. The step of converting crisp to fuzzy is calling FUZZIFICATION.

Genetic Algorithms imitate the natural way of selection [21]. Search for the solution by repeat generation after generation the try-and-error method.

- The population of individuals: each of them is a set of property and defines the behaviour of the solution. Also, subject to variation when the individual reproduces.
- Operators: the new individual birth defines by operators. Including:
  a) Crossing: the property of two individuals combined to create a new improved individual.
  b) Mutation: a new individual is producing by copying another individual and introducing a few changes.
- fitness function: give a degree to the solution according to their quality
- Reproduction: as mentioned before new individuals created by crossing, mutation, or combine of both of them. Sometimes a high rate of mutation produces a high ratio of exploration.
- Evaluation: this value defines an individual to survive and reproduce in the next generation.
- Selection: this step decides about rules that survive. The higher fitness the more chance of surviving.

Genetic Fuzzy Learning for Diagnosis in Cellular Networks data sets format is as:

Figure 7. Format of training data

Which include several PIs value and class diagnosed fault cause corresponding label. Diverse aspects may have influenced the statistical of each PI's behaviour. Including configuration, location of the originating sector, distribution of users, etc. because they need for each section is different so a usual value for a section may be unusual for another section. This difference is managing in the FUZZIFICATION process.

There are many counters and indicators in a cellular network that can be used as symptoms but operators focus on a limited subset of PI to find the root cause during the troubleshooting. The subset may be different because it depends on which fault, they are looking for. So, the system will allow incomplete (the rules that do not need a value for every input variable) rules. This will let FLC find cases with more than one fault cause simultaneously. Thus, rules in troubleshooting must only include information about effected PIs.

4. KPIs Definition

The following KPIs is used as input to test the systems

RSRP: Reference Signal Received Power. RSRP measurement is important to re-rank the different cell-cell, which will use for handover and cell reselection algorithm. Besides, RSRP defines measurement frequency bandwidth, which is the contributions power average of resource parts that carry the reference signal in OFDM symbols carrying the reference signal.

RSSI: (Received signal strength indicator). It is the total power of the signal that received by users in a special frequency range including noise and interference

RSRQ: (Reference Signal Received Quality) when RSRP is not enough to decide about cell reselection or handover, the RSRQ provides more information to decide.

HOSR: Handover success rate. This is the ratio between succeed handovers to total handovers and describe the network's ability to give service to users while they are on movement.

E_RAB_RET: describe the ability of the network to hold a connection for the eligible period.

AVG_THROUGHPUT: the average number of the user throughput.

50_PERC_DIST: Depicts where the majority of users are located concerning the center of the serving cell base station.

5. Comparison of Methods

The heading of the Appendix section must not be numbered. Appendixes, if needed, appear before the acknowledgment.

5.1. Root Causes Diagnose Compare

The Propose of this section is to compare these approaches to root cause diagnosis methods. There were no roots cause analysis in resources about the RSRP mechanism and BIG data so they won't be in comparator table. Although the BIG data will have parts in total compare and conclusion, the RSRP mechanism will not, because it uses only one KPI and can't do any root cause analysis.

The inputs of Table 1 are the information from reference articles. There were many items but we could find some items that were common in all of them. Table 1 includes six items in columns which are root causes. And rows are the approaches. Comparator Table shows us the result of each approach to root causes in percent.

From the result, it can be concluded that genetic fuzzy is failed. It's because of the algorithm. As mentioned earlier the genetic fuzzy needs KPIs to create rules and in a real network there are a lot of KPIs but in these simulations, there are just a few of KPIs so genetic fuzzy can't operate well. The comparator chart is as below. While genetic fuzzy is completely zero and adaptive root cause couldn't identify any EU, RP, and ED so we got 3 approaches to compare. SVM act much better than genetic fuzzy but it didn't find any CH. Also, it has lower TLHO and RP and ED value than Fuzzy logic-based and ADABOOST. ADABOOST is better than SVM. More diagnosis in all items makes it a reliable approach. ADABOOST diagnose RP better than Fuzzy logic-based but less diagnosis rate on ED, EU, TLHO, II. The difference is not too much but we are looking for the best approach. Fuzzy logic-based act better than all systems, it has the highest values except for RP which ADABOOST has it. According to the data of Table 1 and comparator chart, Fuzzy logic-based is the best approach in root cause methods but it doesn't mean the other is useless, as mentioned earlier ADABOOST operates as good as Fuzzy logic-based. Also, these are the result of a simple simulation with few KPIs and some approach operates better when they are more KPIs. So, the use of the approaches is according to the network and its density.

Table 1. Root causes diagnose compare table

R	Item	SVM %	ADA BOOST %	Adaptive Root Cause Analysis	Fuzzy logic based %	Genetic Fuzzy %
1	CH	0	81.5	18	81.5	0
2	II	97.2	96.2	15	98	0
3	TLHO	57.8	94.6	60	96	0
4	EU	96.7	95.7	0	99	0
5	RP	70.7	99	0	94	0
6	ED	75.4	96	0	99	0

From the result, it can be concluded that genetic fuzzy is failed. It's because of the algorithm. As mentioned earlier the genetic fuzzy needs KPIs to create rules and in a real network there are a lot of KPIs but in these simulations, there are just a few of KPIs so genetic fuzzy can't operate well. The comparator chart is as below. While genetic fuzzy is completely zero and adaptive root cause couldn't identify any EU, RP, and ED so we got 3 approaches to compare. SVM act much better than genetic fuzzy but it didn't find any CH. Also, it has lower TLHO and RP and ED value than Fuzzy logic-based and ADABOOST. ADABOOST is better than SVM. More diagnosis in all items makes it a reliable approach. ADABOOST diagnose RP better than Fuzzy logic-based but less diagnosis rate on ED, EU, TLHO, II. The difference is not too much but we are looking for the best approach. Fuzzy logic-based act better than all systems, it has the highest values except for RP which ADABOOST has it. According to the data of Table 1 and comparator chart, Fuzzy logic-based is the best approach in root cause methods but it doesn't mean the other is useless, as mentioned earlier ADABOOST operates as good as Fuzzy logic-based. Also, these are the result of a simple simulation with few KPIs and some approach operates better when they are more KPIs. So,

the use of the approaches is according to the network and its density.

5.2. Total Compare

In this section, BIG data will join others for total comparison. The target of this section is to compare all systems' behavior in fault detection. Without attention to faults kind and its root cause. Compare items are ED, Eu, and FPR.

Table 2. Total diagnose compare table

R	item	SVM %	ADA BOOST %	Adaptive Root Cause Analysis	Fuzzy logic-based %	Genetic Fuzzy %	Big data %
1	DER	8.6	2.86	2.15%	2.67	0	2.27
2	UER	19.6	2.10	16%	13.68	62.4	15
3	FPR	1.2	2.06	5%	0.1	10.1	0

As mentioned before RSRP is out of the Table 2. SVM has the highest value of DER and low FPR. SVM acted better in total compare but can't pass high UER in Table 2 and the low quality on root cause table. ADABOOST has the lowest UER and normal value on DER and FPR. According to its result on the root cause table, it can be considered as a good approach. Adaptive Root Cause Analysis has a high value of UER and FPR and also a normal value of DER which makes it a low-quality approach. Fuzzy logic-based operate as good as root cause table, very low FPR value, and normal DER but it has a high value of 13.68% on UER which is not a good value. Genetic fuzzy failed again with no detection, highest UER and FPR. As mentioned before, the genetic fuzzy result has great relation to the number of KPIs. Big data has the best and lowest FPR and a normal value of DER but high UER. It has a normal action but since it wasn't in root.

6. Conclusions

According to these tables and charts, it can be concluded that three items Fuzzy logic-based, ADABOOST, and BIG DATA are better and more reliable than others. Choose the best approach to use in a network between these items depends on many things like network KPIs and situation and its density. But in simulation network, Fuzzy logic-based act better than others and ADABOOST is next.

References

[1] N. A. Golilarz, N. Robert, J. Addeh, A. Salehpour, Translation invariant wavelet based noise reduction using a new smooth nonlinear improved thresholding function, Computational Research Progress in Applied Science & Engineering 3 (2017) 104–108.

[2] N. A. Golilarz, H. Demirel, Thresholding neural network (TNN) based noise reduction with a new improved thresholding function, Computational Research Progress in Applied Science & Engineering 3 (2017) 81–84.

[3] Addeh, A. Khormali, N. A. Golilarz, Control chart pattern recognition using RBF neural network with new training algorithm and pracrical features, ISA Transactions 79 (2018) 202–216.

[4] N. A. Golilarz, A. Addeh, H. Gao, L. Ali, A. M. Roshandeh, H. M. Munir, R. Khan, A new automatic method for control chart patterns recognition based on ConvNet and harris hawks meta heuristic optimization algorithm, IEEE Access 7 (2019) 149398–149405.

[5] H. Shokouhandeh, M. Ghaharpour, H. G. Lamouki, Y. R. Pashakolaei, F. Rahmani, and M. H. Imani, Optimal Estimation of Capacity and Location of Wind, Solar and Fuel Cell Sources in Distribution Systems Considering Load Changes by Lightning Search Algorithm, in 2020 IEEE Texas Power and Energy Conference (TPEC) (2020) 1–6.

[6] M. Khatibi, T. Amraee, H. Zargarzadeh, and M. Barzegaran, Comparative analysis of dynamic model reduction with application in power systems, in 2016 Clemson University Power Systems Conference (PSC) (2016) 1–6.

[7] M. Khatibi and S. Ahmed, Optimal resilient defense strategy against false data injection attacks on power system state estimation, in 2018 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT) (2018) 1–5.

[8] M. Ketabdar, Numerical and Empirical Studies on the Hydraulic Conditions of 90 degree converged Bend with Intake, International Journal of Science and Engineering Applications 5 (2016) 441–444.

[9] F. Rahmani, Electric Vehicle Charger based on DC/DC Converter Topology, International Journal of Engineering Science 18879 (2018).

[10] X. Liu, G. Chuai, W. Gao, Y. Ren, and K. Zhang, Diagnosis Based on Machine Learning for LTE Self-Healing, in International Conference in Communications, Signal Processing, and Systems (2017) 2096–2105.

[11] M. Khatibi, H. Zargarzadeh, and M. Barzegaran, Power system dynamic model reduction by means of an iterative SVD-Krylov model reduction method, in 2016 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT) (2016) 1–6.

[12] M. Khatibi, S. Ahmed, Impact of Distributed Energy Resources on Frequency Regulation of the Bulk Power System, arXiv preprint arXiv:1906.09295 (2019).

[13] H. Mfula and J. K. Nurminen, Adaptive root cause analysis for self-healing in 5G networks, in 2017 International Conference on High Performance Computing & Simulation (HPCS) (2017) 136–143.

[14] L. Ali, S. Khan, N. A. Golilarz, Y. Imrana, I. Qasim, A. Noor, R. Nour, A Feature-Driven Decision Support System for Heart Failure Prediction Based on χ 2 Statistical Model and Gaussian Naive Bayes, Computational and Mathematical Methods in Medicine (2019) 1–8 .

[15] F. Rahmani, F. Razaghian, and A. Kashaninia, Novel Approach to Design of a Class-EJ Power Amplifier Using High Power Technology, World Academy of Science, Engineering and Technology, International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering 9 (2015) 541–546.

[16] Gómez-Andrades, P. Muñoz, E. J. Khatib, I. de-la-Bandera, I. Serrano, and R. Barco, Methodology for the design and evaluation of self-healing LTE networks, IEEE Transactions on Vehicular Technology 65 (2015) 6468–6486.

[17] F. Rahmani, F. Razaghian, and A. Kashaninia, High Power Two-Stage Class-AB/J Power Amplifier with High Gain and Efficiency (2014).

[18] E. J. Khatib, R. Barco, A. Gómez-Andrades, and I. Serrano, Diagnosis based on genetic fuzzy algorithms for LTE self-healing, IEEE Transactions on vehicular technology 65 (2015) 1639–1651.

[19] R. Nofitasari and S. Haryadi, Self-healing mechanism with RSRP measurement in LTE network, in 2017 3rd International Conference on Wireless and Telematics (ICWT) (2017) 144–148.

[20] E. J. Khatib, R. Barco, P. Muñoz, I. De La Bandera, I. Serrano, Self-healing in mobile networks with big data, IEEE Communications Magazine 54 (2016) 114–120.

[21] I Bargegol, M. Nikookar, R. V. Nezafat, E. J. Lashkami, A. M. Roshandeh, Timing optimization of singalized intersections using shockwave theory by genetic algorithm, Computational Research Progress in Applied Science and Engineering 1 (2015) 160–167.