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Data Reduction and Neural Networking Algorithms to Improve Intrusion Detection System with NSL-KDD Dataset

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ABSTRACT

Most of the researchers have argued that Artificial Neural Networks (ANNs) can improve the performance of intrusion detection systems (IDS). The central areas in network intrusion detection are how to build effective systems that are able to distinguish normal from intrusive traffic. In this paper we have used data reduction algorithm cfs Subset and four different neural networking algorithms namely Multilayer Perception, Stochastic Gradient Descent, Logistic Regression and Voted Perception. All these algorithms are implemented in WEKA data mining tool to evaluate the performance. For experimental work, NSL-KDD dataset is used. First we reduce data set by data reduction algorithm after this each neural based algorithm is tested with conducted dataset. The results show that the Multilayer Perception neural network algorithm is providing more accurate results than other algorithms.

Keywords:-Data Mining, Intrusion Detection System, Neural Network Algorithm, NSL-KDD dataset

1.INTRODUCTION

With the tremendous growth of computer networks mostly computer system suffers from security vulnerabilities which are difficult to handle technically as well as economically by users [27]. Data mining is the process of discovering interesting knowledge from large amounts of data stored in databases, data warehouses, or other information repositories. The overall goal of the data mining process is to extract information from a data set and transform it into an understandable structure for further use [28]. It is the computational process of discovering patterns in large data sets involving methods at the intersection of artificial intelligence, machine learning, and database systems. Data mining applications can use a variety of parameters to examine the data.

Data reduction is a process in which amount of data is minimized and that data is stored in a data storage environment. By data reduction algorithms massive data-set is reduced to a manageable size without significant loss of information represented by the original data. With this process various advantages have achieved in computer networks such as increasing storage efficiency and reduce computational costs. There are two important motivating factors of data reduction, first is redundancy and second is reduction of complexity regarding live network acquisition [2].

Data reduction technique can be applied to obtain a reduce representation of the data set that is much smaller in volume, yet closely maintains the integrity of the original data. That is, mining on reduced data set should be more efficient yet produce the same (or almost the same) analytical results. For very large data sets, there is an increased likelihood that intermediate, additional steps, data reduction, should be performed prior to applying the data reduction techniques. Three basic operations in data reduction process are: delete a column, delete a row, and reduce the number of column.

The larger data sets have more useful information with decreasing storage efficiency and increasing computational costs. Data reduction is not something separate from analysis. It is part of analysis. The researcher's decisions—which data chunks to code and which to pull out, which evolving story to tell—are all analytic choices. Data reduction is a form of analysis that sharpens sorts, focuses, discards, and organizes
data in such a way that "final" conclusions can be drawn and verified [3].

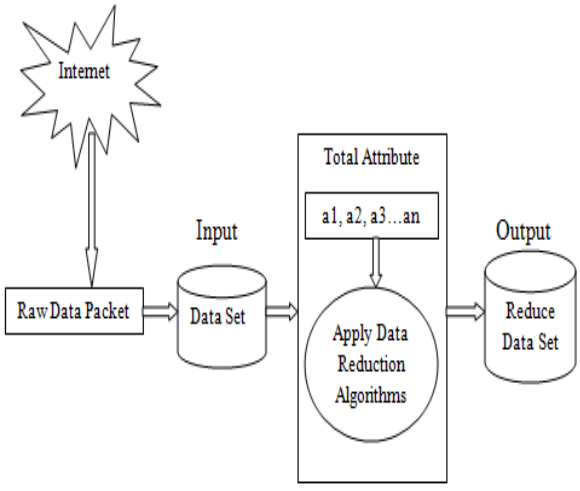

Fig1. Block diagram of data reduction [32]

Data deduplication and compression of primary and secondary data brings a lot of benefits to an organization. Whether it is saving on the amount of disk space consumed by the backup process or on expenditures for additional storage capacity, the data reduction market is growing. It is becoming a necessary capability for most organizations when they look for backup software. There is confusion, however, in how different vendors implement their data deduplication – whether inline or

post-processing is better, whether data should be compressed in variable length or fixed length blocks, and what the advantages of compressing data from the get-go are [4].

With the development of internet, network security becomes an indispensable factor of computer technology. The concept of Intrusion Detection System (IDS) proposed by Denning (1987) is useful to detect, identify and track the intruders. An intrusion detection system (IDS) is a device or software application that monitors network or system activities for malicious activities or policy violations and produces reports to a management station. The intrusion detection systems are classified as Network based or Host based attacks. The network based attack may be either misuse or anomaly based attacks. The network based attacks are detected from the interconnection of computer systems. The host based attacks are detected only from a single computer system and is easy to prevent the attacks. Data mining can help improve intrusion detection by adding a level of focus to anomaly detection [28]. It helps in to classify the attacks to measure the effectiveness of the system. Classification is the process of finding the hidden pattern in data. With the use of classification technique it is easy to estimate the accuracy of the resulting predictive model, and to visualize erroneous predictions. The goal of classification is to accurately predict the target class for each case in the data. In Data Mining, neural network plays a vital role. They help in to providing information on associations, classifications, clusters, and forecasting. In our research, various neural network algorithms are used which are helpful in to classify and analyze the attacks in an efficient manner.

2. RELATED WORK

In network huge amount of data should be processed, and the data contains redundant and noisy features causing slow training and testing process, high resource consumption as well as poor detection rate. For this we reduce the data.

Tao et. al. [1] proposed the Manifold learning algorithm Based Network Forensic System. Manifold learning is a recent approach to nonlinear dimensionality reduction. The idea behind manifold learning is that dimensionality of many data sets is only artificially high. Each manifold learning algorithm used a different geometrical property of the underlying manifold. They are also called spectral methods, since the low dimensional embedding task is reduced to solving a sparse Eigen value problem under the unit covariance constraint. However, due to this imposed constraint, the aspect ratio is lost and the global shape of the embedding data can not reflect the underlying manifold. Manifold learning is a popular recent approach to nonlinear dimensionality reduction. For nonlinear dimensionality reduction needs three steps (i) Locally Linear Embedding Algorithm. (ii) Data Processing of the Data Set. (iii) Data Reduction with LLE.

Willetty et al [4] proposed Data Reduction Techniques. They have applied several data reduction technique in available datasets with the goal of comparing how an increasing level of compression affects the performance of SVM-type classifiers. Several data reduction techniques are applied to three datasets (WDBC, Ionosphere and PHM). The comparison of these techniques was based on how well the data can be classified by an SVM or PSVM (linear and nonlinear versions for each) at decreasing number of components retained. One dataset proved to be hard to classify, even in the case of no dimensionality reduction. Also in this most challenging dataset, performing PCA was considered to some advantages over the other compression techniques. Based on our assessment, data reduction appears a useful tool that can provide a significant reduction in signal processing load with acceptable loss in performance.

Fodo et al [9] proposed a survey of dimension reduction techniques. During the last ten year data collection and storage capabilities have include information overhead in sciences. Increase the number of observations, traditional statistical methods break are down partly. The dimension of the data is that measured on each observation. High-dimensional datasets present many mathematical challenges as well as some opportunities and rise new theoretical developments. In high-dimensional datasets, for understanding the underlying phenomena of interest all measure variables are not important. Some computationally expensive novel methods can construct predictive models with high accuracy from high-dimensional data. Various applications are used to reduce the dimension of original data without loss of any information.

Robert et al [10] proposed Novel Data Reduction Technique. Large-scale networks generate enormous numbers of events that determine which are malicious attacks and which are not. In network analyst's first most severe attack are resolved in order to limit the potential for damage to the network as much as possible. There are many data reduction and event correlation technique for reducing the amount of data needing analysis; these techniques do not provide prioritization capabilities. In this, identifying and resolving the most critical events first. Impact assessment technique identifies the potential impact. Impact assessment improves the efficiency of the analysis process and reduces the amount of data needing to be transmitted over the network.

Furtado et al [11] proposed Analysis of Accuracy of Data Reduction Techniques. Data warehouse is a growing interest in the analysis of data. Data warehouse can frequently take extremely large and typical queries. Obtain the best estimates which have smaller response times and storage need by data reduction techniques. In this paper apply the simple data reduction technique in several data sets to analysis the accuracy. Data cube density and distribution skew are important parameters and large range queries are approximated much more accurately then point or small range queries.

Joshua et al [12] proposed a global geometric framework for nonlinear dimensionality reduction. They have used some classical technique such as principal component analysis (PCA), multidimensional scaling (MDS) to

solved dimensionality reduction problems that determine local information to learn with the basis of global geometric of a data set. We analysis nonlinear degree of freedom that is lies in complex natural observation. Aim was to use nonlinear dimensionality reduction algorithms to determine a globally optimal solution for vital class of data main fold.

Mahbod et al. [29] has described that researcher has overcome the weakness of signature-based IDSs in detecting novel attacks, and KDD' 99 cup is the mostly widely used data set for the evaluation of these systems. KDD'99 cup faces two main issue which effects the performance of system. Therefore a new data set, NSL-KDD, has been proposed which does not suffer from any mentioned shortcomings. The Intrusion Detection System which uses Radial Base Function Neural network , prioritize the speed and efficiency of the training phase and also limits the false alarm rate and

results shows that the radial Basis Functions Neural Networks provide better detection rate and very low training time.

Rohit et al. [30] have compared the two classification algorithm J48 and Multilayer Perception to analyzed better performance. For this, they test the several dataset with the help of data mining tool WEKA. After comparing both algorithms it found that, Multilayer Perception is better algorithm in most of the cases.

Sneha et al. [31] has explained that how Data mining is useful to detect attacks in Intrusion Detection System. Data mining provides a wide range of techniques to classify and identifies attacks They provides a comparative study on the attack detection rate of these existing classification techniques in data mining.

3. ALGORITHMS

3.1 DATA REDUCTION ALGORITHMS

Data reduction is the process of minimizing the amount of data that needs to be stored in a data storage environment. Data reduction can increase storage efficiency and reduce costs. We used WEKA tool for data reduction. Here we are using different data reduction technique for reduced KDD 99 data set.

CfsSubset Attribute Evaluator: - CFS evaluates the worth of a subset of attributes by considering the individual predictive ability of each feature along with the degree of redundancy between them. Correlation coefficients are used to estimate correlation between subset of attributes and class, as well as inter-correlations between the features. Relevance of a group of features grows with the correlation between features and classes, and decreases with growing inter-correlation. CFS is used to determine the best feature subset and is usually combined with search strategies such as forward selection, backward elimination, bi-directional search, best-first search and genetic search [13].

3.2 Neural Network Algorithm

A. Logistic - Logistic regression or Logistic is a type of regression analysis used for predicting the outcome of a categorical dependent variable based on one or more predictor variables. That is, it is used in estimating empirical values of the parameters in a qualitative response model. Logistic regression measures the relationship between a categorical dependent variable and one or more independent variables. It can be binomial or multinomial. Binomial or binary logistic regression refers to the instance in which the observed outcome can have only two possible types (for example, "dead" vs. "alive"). Multinomial logistic regression refers to cases where the outcome can have three or more possible types (e.g., "better" vs. "no change" vs. "worse").

B. Voted Perceptron- Voted Perceptron neural network is based on perceptron algorithm. The algorithm takes advantage of data that are linearly separately with large margin. This methods is easy to implement and much more efficient in terms of computational time. Voted Perceptron neural network helps in replaces all missing values, and transforms nominal attributes into binary one. It helps in to predicting the outcome in binary one. In voted perceptron, more information can be store during training and then use this elaborate information to generate better prediction on test the data.

C.Multilayer Perceptron- A multilayer perceptron (MLP) is a feed forward artificial neural network model that maps sets of input data onto a set of appropriate outputs. An MLP consists of multiple layers of nodes in a directed graph, with each layer fully connected to the next one. Except for the input nodes, each node is a neuron (or processing element) with a nonlinear activation function. MLP utilizes a supervised learning technique called back propagation for training the network. . The multilayer perception consists of three or more layers (an input and an output layer with one or more *hidden layers*) of nonlinearly-activating nodes. The main advantages of this method are that they are easy to use, and that they can approximate any input/output map.

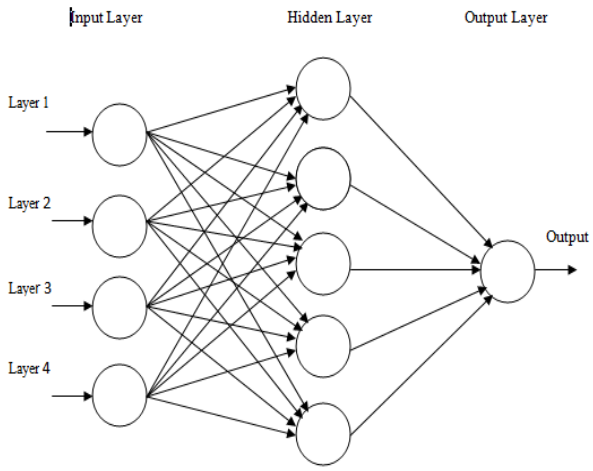

Fig2. General structure of Multilayer Perceptron Neural Network

D.SGD Network- Stochastic gradient descent is a gradient descent optimization method for minimizing an objective function that is written as a sum of

differentiable functions. Due to the inherently sequential nature of stochastic gradient descent, the algorithm does not readily benefit from being run in parallel or distributed system environments. It is a common choice among optimization algorithms in machine learning. As such, there are several variants of SGD which aim to address this network.. The algorithm operates without locking (asynchronously) the decision variable. This method is effective when the data set being operated on is sparse (ultimately, this requires infrequent updates to the decision variable).

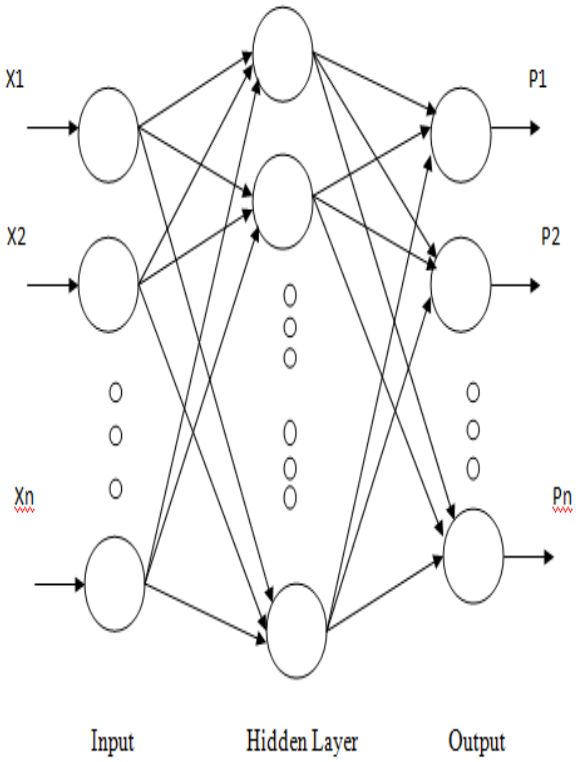

Fig3. General structure of SDG Neural Network

4. PROPOSED FRAMEWORK

a) **Preprocessing-** Firstly, NSL KDD dataset has been selected for classify purpose. There are 25192 classified instances and 42 attributes in this dataset.

(b) Select Tool- After selecting the dataset, the next step is to load the dataset in proposed WEKA machine learning tool.

(c) **Select Algorithm-** When the dataset has been loaded in the WEKA tool, first we apply the data reduction algorithms and get reduce data set after this next step is to test the dataset to measure the detection rate by selecting particular algorithm at a time in reduce data set.

(d) **Cross Validation-** In this step, the dataset has been tested with the help of selected neural algorithm separately, for classifying the attacks or to measure the accuracy.

(e) **Performance Analysis-** The last step, where the performance of each algorithm is evaluated and compared with respect to each other.

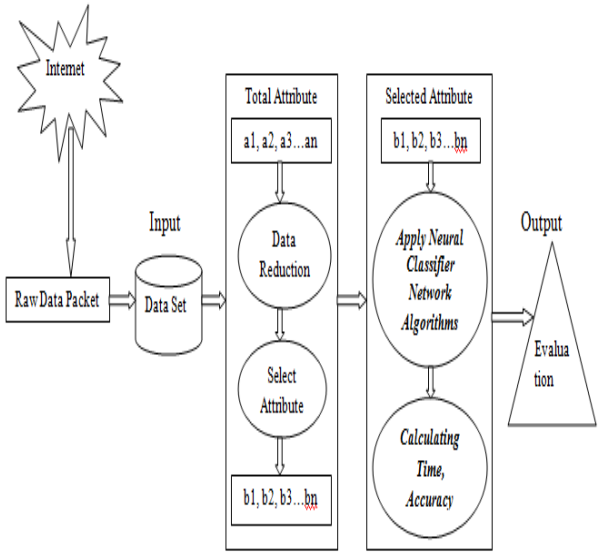

Fig4. Block diagram of proposed technique

5. EXPERIMENTS AND RESULTS

To evaluate the performance of our approach, a series of experiments were conducted. These experiments by implementing proposed intrusion detection system in machine learning tool.

Table1. Building blocks of IDS system

TYPE	NAME	SOURCE
Tool	WEKA	www.cs.waikato.ac
Dataset	NSL KDD	UCI 99
Algorithm	Logistic, MPNN,SGD, Voted Perceptron	Data mining Neural ClassifierAlgorithm
Result	Microsoft Office Excel	Microsoft Office

a) **WEKA TOOL-** We have used WEKA toolkit to analyze the dataset with data mining algorithm. WEKA is open source

Application formally called Waikato Environment for Knowledge Learning is a computer program that was developed at the University of Waikato in New Zealand for the purpose of identifying information from raw data gathered from agricultural domains. It supports many different standard data mining tasks such as data pre-processing, classification, clustering, regression, visualization and feature selection. The basic premise of the application is to utilize a computer application that can be trained to perform machine learning capabilities and derive useful information in the form of trends and patterns. WEKA operates on the predication that the user data is available as a flat file or relation, this means that each data object is described by a fixed number of attributes that usually are of a specific type, normal alpha-numeric or numeric values. The WEKA application allows novice users a tool to identify hidden information from database and file systems with simple to use options and visual interfaces.

(b) **NSL KDD Dataset-** NSL-KDD is a data set used to solve some of the inherent problems of the KDD'99 data set. The new version of the KDD data set still suffers from some of the problems and may not be a perfect representative of existing real networks, because of the lack of public data sets for network-based IDSs, we believe it still can be applied as an effective benchmark data set to help researchers compare different intrusion detection methods. In NSL-KDD dataset there is no duplicate records in the proposed test sets; therefore, the performance of the learners are not biased by the methods which have better detection rates on the frequent records. This dataset contains number of attributes, which are supportive for measure the attacks.

(c) **Algorithm-** In data mining, neural network classifier algorithm are used to classify the data in well organized form. The selected dataset is test with data mining algorithms. There are four types of data mining algorithm namely as Multilayer Perception, Radial Base Function, Logistic and Voted Perception are used to evaluate the performance. All these algorithms individually tested on a dataset.

(d) **Results-** The performance of each tested algorithm on a selected dataset is graphically exposed with the help of Microsoft Office Excel. It makes easy to understand performance of each classifier on a conducted dataset.

6. PERFORMANEC AND EVALUATION

Here first step we apply preprocessing in weka for NSL KDD data set after this apply data reduction algorithm (cfs Subset) in weka tool and get reduced data set with 6 attributes which is shown in table2. In next step applying cross validation on all four neural network algorithms, the performance of each algorithm on a conducted dataset is evaluated and the following results are obtained with accuracy, time, Kappa Statistic, MAE, RMES, RAE and RRS.

Table2. Attributes after applying data reduction Algorithms

	Volume (Mb)	No. of Selected Attributes	Unpotential Attributes
KDD FULL DATASET	20.4	42	0
Cfs Subset Eval	10.8	6	36

Table3. Performance Measure Result

ALGORITHM	CCI	ICI	KAPPA STATISTIC	MAE	RMSE	RAE	RRSE	Time Taken(s)
Logistic	97.1	2.89	0.94	0.03	0.15	8	48.28	44.25
Multilayer Perceptron	98.27	1.73	0.98	0.02	0.11	3.34	29.37	66..45
SGD	97.55	2.45	0.95	0.02	0.15	4.91	31.36	71.61
Voted Perceptron	88.19	11.88	0.76	0.09	0.26	10.78	68.87	104.98

From a table 3, the graphical representation of evaluated parameter resulted by individually tested neural network algorithm is shown above.

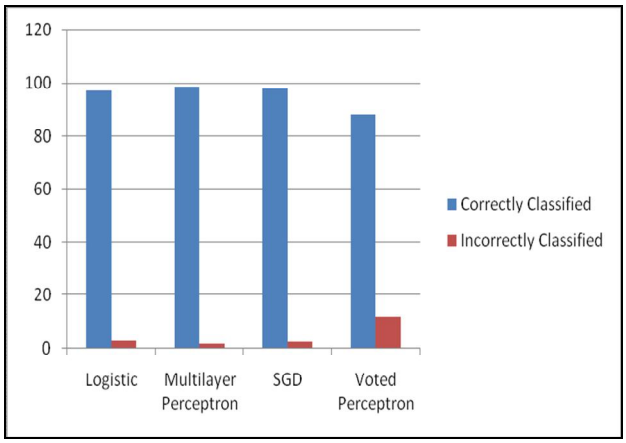

FIG5. ACCURACY OF ALGORITHM

Fig 5 describes the correctly classified instances and the incorrectly classified instances of each algorithm. After classification of NSL KDD test dataset it is clearly shown that the Multilayer Perceptron algorithm shows the higher detection accuracy among all other algorithms.

Kappa is a chance-corrected measure of agreement between the classifications and the true classes. It's calculated by taking the agreement expected by chance away from the observed agreement and dividing by the maximum possible agreement. A value greater than 0 means that classifier is doing better than chance. After cross validation, Fig 6 clearly shows that the Multilayer Perception algorithm performs more classifier accurate result than among other neural algorithms. Classifier accuracy of Multilayer Perceptron neural algorithm is 98% which is superior as compared to others.

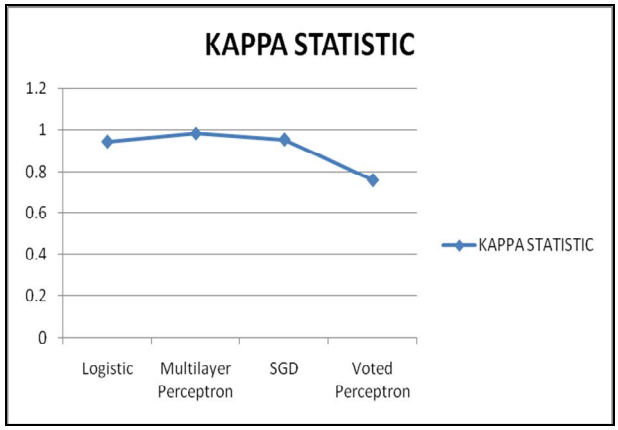

FIG6. KAPPA STATISTIC

The Mean Absolute Error measures the average magnitude of the errors. Fig 7 indicates that Voted Perceptron neural network have highest mean absolute error rate. Like Mean Absolute Error, the Root Mean Squared Error is a quadratic scoring rule which measures the average magnitude of the error but in this case corresponding observed values are each squared and then averaged over the sample. From a fig 7, it is clear that

Voted Perceptron neural has the highest Root Mean Squared Error rate as compare to other networks.

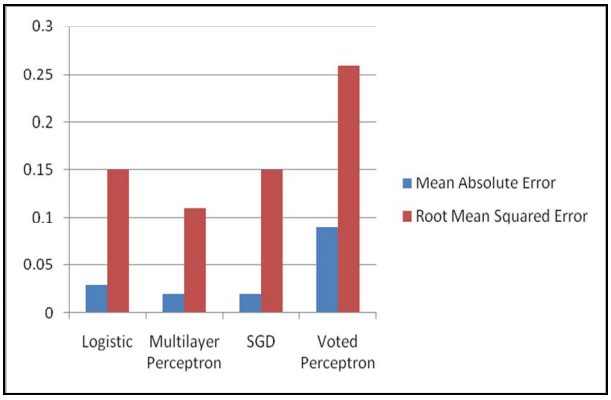

Fig7. MAE v/s RMSE

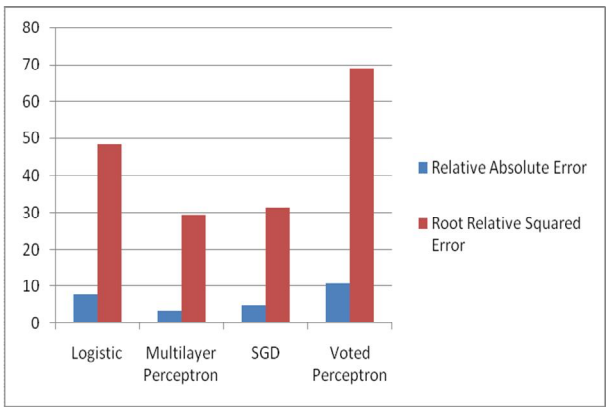

Fig8. RAE v/s RRSE

The relative absolute error is very similar to the relative squared error in the sense that it is also relative to a simple predictor, which is just the average of the actual values. Fig 8 clearly exposed that Multilayer Perceptron neural algorithm has the lowest relative absolute error rate. The Root-mean-square error (RMSE) is used to measure the difference between observed and the predicted value. After doing cross validation, we assume that that Multilayer Perceptron neural algorithm evaluated the lowest root relative squared error rate.The fig 9 shows the average computational time taken by neural algorithm to test a model on training data. After classifying all neural algorithm or cross validation it is clearly shown that the Voted Perceptron neural network has taken more time to build a model on training data than the rest of among the neural network algorithms.

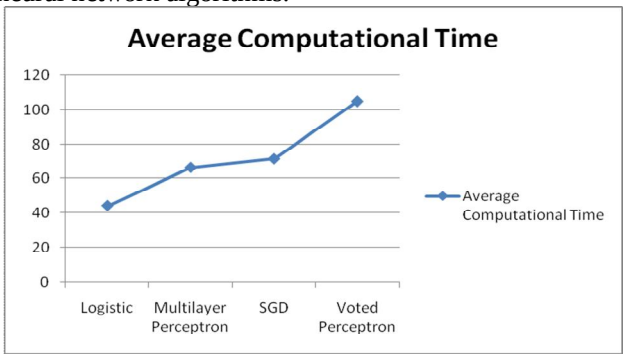

Fig9. Computational Time Taken

7. CONCLUSION AND FUTURE WORK

This study is approached to discover the best classification for the application machine learning to intrusion detection. For this, we have presented different neural based data mining classifier algorithms to classify attacks in an efficient manner. After doing experimental work, it is clear that Multilayer Perceptron feed forward neural network has highest classification accuracy and lowest error rate as compared to other neural classifier algorithm network. To enhance the results the feature reduction techniques is applied. The neural algorithms are applied to NSL KDD dataset by reducing its attributes and implemented using WEKA machine learning tool. We showed that machine learning is an effective methodology which can be used in the field of intrusion detection. In future, we will propose a new algorithm which will integrate Multilayer Perception Network with fuzzy inference rules to improve the performance.

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