Our proposed IDS model is described in figure []. The system has 5 Mamdani FIS namely []. Each FIS has two inputs and one output. Each input has 2 membership functions, L (Low) and H (High). The output has 3 membership functions that are FA (False Attack), MA (Medium Attack), and HA (High Attack) functions. Inference rules and output membership functions are fixed. The output membership functions evaluate the probability of each point can be classify into the respectively class in the FIS’s name.

The DtoN module takes the responsibility of transformation between the distance matrix D and the density matrix N. Matrix D can be obtained by calculating the distance of each point to the remaining points in the dataset., N is a two-column matrix containing the number of points which have the same label as the label of the FIS and the number of points which have other labels whose distance from each data point is less than or equal to r

initialization phase

For each FIS, labels in the data set are encoded (1 if the label is the same as the label in the FIS’s name, otherwhile it is encoded as 0)

Training\_set and Valid\_set are utilized in this phase. In the Training\_set, the distance is calculated to the rest of the set points to obtain the D\_train distance matrix, D\_train. The radius r is initialized random between [0 avg(D\_train)]. Based on the label of the FIS, the DtoN module calculate N\_train matrics for each FIS. Each N\_train matrix then divided by its maximum value and limited to the interval [0 1]. Moreover, the distance between each point in the Valid\_set and each point in Training\_set is calculated to obtain the distance matrix, D\_val. Then the same process is used to obtain N\_val matrix.

N\_train and N\_val are fed into each FIS. Each input membership function has a trapezoid shape characterized by four parameters (a, b, c, d). In order to optimize these parameters with TLBO algorithm, we encoded them into a set of three parameters (x, y, z) as follows:









The parameters after encryption of the input member functions are randomly initialized between 0 and 1. We combine the input membership function parameters and radius r to form a particle of length 13 for the TLBO algorithm. We initialize a population of 50 particles and use them in the next phase.

Optimization phase

For each iteration, each particle calculates its fitness value (*fit*) based on the cost function J. The output of the FIS is a value in the range [0 1]. This value is then compared with the corresponding binary-encoded label. The cost function and fitness value’s formulas can be expressed as:





Where: n is the total number of samples of the test set.

 is the  sample of the test set

 is the  label of the test set

 is the predictive output of the model given the input is the  sample of the test set

The particle which has the maximum fitness value of the population can be seen as the current iteration’s best solution. We use this solution to calculate the validate value (val) using the above equations. The TLBO algorithm utilize *fit* and *val* to find the best solution after a number of iterations. This training process is repeated for every FIS in the model.

After the training phase, the proposed model will be tested and evaluated using the Test\_set. For each data point, output values from 5 FISs are compared and the data point is classified into the label which has the maximum FIS’s output value. This result is then compared with the original labels in the Test\_set to calculate evaluation metrics.