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## Fuzzy Neural Network for Dynamic load balancing of nodes for ad hoc network using

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### Abstract

In ad hoc network, many traffic types reach continually with different rates and with different times. There are three cases of rates (low, medium and high) which depending on the capacity of links. The performance of ad hoc network is reducing when an imbalance load of traffic occurs among the links or nodes. There is a necessary thing to use a technique to provide load balancing between the nodes (or links) of network that leading to destination node for the arrival traffic rates, so as to avoid exceeding the traffic rates on the viability of nodes (or links).

In this paper, a system based on fuzzy neural networks (FNNs) is proposed for solving the load balancing problem in the Ad hoc networks to achieve dynamic load balancing is facing continuous changes in the network. The proposed fuzzyneural system (FNS) is located at each point in the network to make load balancing for nodes using two fuzzy neural networks , firstly,FNN1 based on two measurements which are queue length, whichpermitqueue size to classify queue state ( Under –full ..... Over – full). Secondly, FNN2 used queue state that represented output of the FNN1, while the other is throughput for node and the output is load for this node.The Gaussian member ship function is used with backpropagation algorithm for training the NN.

**Keywords:** ad hoc networks,load balance, fuzzy logic, neural networks

### 1. Introduction

Generally, in computer network, load balancing is important for distributing the load of traffic across several links from the source in order to reach its destination, where, the most important reason to reduce network efficiency is that the load is greater than the capacity of network. So the objective of the load balancing created the fairness in sharing the transmission channel. Therefore, improving load balancing became an

important hot subject in communication network researches especially in mobile wireless networks, since wireless communication is currently one of the fastest growing technologies as a result of the recent progress in mobile computing and wireless devices [1].

Wireless networks can be defined as networks in which the nodes are interconnected by wireless links. Due to

increasing development of mobile wireless network there are two main architectures. One of this architecture mobile wireless network is the infrastructure-less mobile network, commonly known as an **ad hoc network**. Infrastructure-less networks has no fixed base station. Each computer can communicate directly with all other wireless enabled computer. Nodes in ad hoc networks not can only be a sender or receiver in a connection, but they can also be responsible for forwarding packets to neighboring nodes to implement the Overall mechanism of routing, it means more than one node that can be used for routing at the same time. Therefore, will make ad hoc networks independent from a central point, but may lead to some particular mobile nodes being unfairly burdened to support many packet-relaying functions and consequently, loading on these hot spots. This load on nodes appears in two major aspects: traffic and power consumption. Load balancing algorithm tries to balance this load [2].

**Therefore Ad-hoc** can be defined as a wireless network temporarily composed of several different devices or uniform and are linked to the devices without an access point or wireless route because the network will be based on direct contact between the card wireless network, is installed on each device for data transfer from one computer to

## 2. Ad hoc network

The history of ad hoc network can be described as a life cycle. This life cycle consisted of three generation network systems. The idea of ad hoc networking established in the early 1970s. At that time, this network called packet radio network (PRNet), and were sponsored by the Defense Advanced Research Projects Agency (DARPA), which evolved in the early 1980s, then improved to into the survivable adaptive radio networks (SURAN) program to support a larger scale

another, in the network and must be as standards-compliant IEEE.[3].

Hybrid systems that include fuzzy logic systems and neural networks are two popular artificial intelligent techniques that are widely used in many applications. Thus, neural networks and fuzzy systems have attracted the growing interest of researchers in various disciplines of engineering and science. Their applications range widely from consumer products to decision analysis [4].

Fuzzy neural network (FNN) are the well-established area within computation intelligence, it is the realizations of the functionality of fuzzy system using neural network. The main advantage of FNN is its ability to combine the advantages of fuzzy system to model a problem domain using a linguistic model instead of complex mathematical model with the learning capabilities of neural network. In addition, the black box nature of neural network paradigm is resolved, as the connection structure essentially defines fuzzy rules. The combinations of neural and fuzzy systems create an adaptive system with sensory and cognitive components. When using fuzzy neural network technique with load balancing of computer network by employing its feature above can increase scalability and high performance for network [5][6].

network by providing a packet switched network to the mobile battlefield in an environment without infrastructure. In the 1990s, the development of notebook computers and other viable communication equipment gave rise to third generation ad hoc network system. At the same time, a lot of works has been done on the ad hoc standards and MANET working group was born [7].

Ad hoc network can be defined as a set of mobile devices communicate among

themselves using wireless transmission without the support of fixed or stationary infrastructure. Also each node in the network can play the role of destination and relay station for packet. The main advantage of Ad Hoc network is low cost of deployment and maintenance because the nodes and wireless hardware are inexpensive and easily available [8].

Simple ad hoc networks with four nodes are shown in figure (1). The outermost nodes are not within transmitter range of each other. However, node1 can be used to forward packets between node2 and node4, the same case to node2, node1 and node3 are acting as a router and all the nodes have formed an ad hoc network.

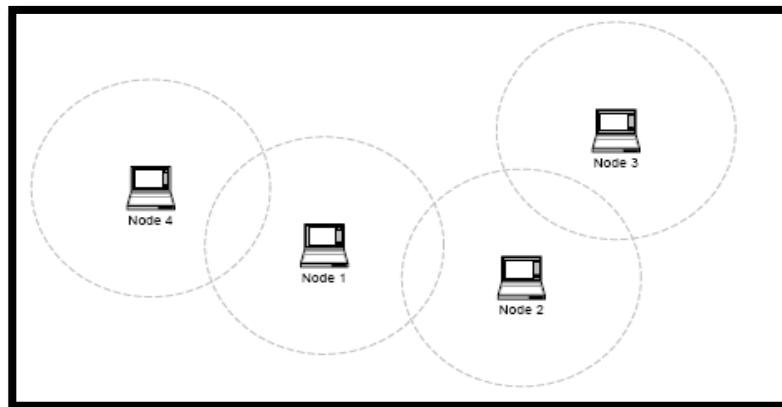


Figure1. Example of simple ad hoc network

There is no centralized administration in the ad hoc network which means any collapse occurs when the mobile's node to move out of the transmitter range of the other [9].

### 3. Fuzzy Neural Network (FNN)

FNN is a core key issue in many various disciplines of engineering and science to classify the acquired data or estimate an unknown function from a set of input-output data pairs. As it is widely known, **fuzzy neural network (FNN)** has been proposed and successfully applied to solve these problems such as classification, identification, control, pattern recognition, and image processing, etc. The need for developing hybrid systems that combine Fuzzy technology and Artificial Neural Networks was motivated by the shortcomings and the complementary nature of each of the two methodologies, therefore, FNN is a hybrid systems which

combined fuzzy system with neural network. Fuzzy system used imprecise data, natural language can be blended with conventional control techniques and can efficiently model non-linear functions of arbitrary complexity, also the main characteristic of ANNs is their ability to learn. The learning process is achieved by adjusting the weights of the interconnections according to some applied learning algorithms [10].

When, FNN attempts to combine the structural and learning abilities of a neural network with the linguistic initialization and validation aspects of a fuzzy system. They are a particular type of fuzzy system that uses

algebraic operators and continuous fuzzy membership functions, and they are categorized by the type of membership functions such as Gaussian fuzzy neural networks. The structure of fuzzy neural network (FNN) is shown in figure( 2 ). This four-layer structure has a construction which is directly based on the fuzzy rules without adjustment, nodes in layer one are input nodes representing input linguistic variables, where nodes

in layer two are membership nodes. Here, the Gaussian function is used as the membership function (MF). Each membership node is responsible for mapping an input linguistic variable into a possibility distribution for that variable. The rule nodes reside in layer three. The last layer contains the output variable nodes. More details about FNNs, convergent theorems and the learning algorithm can be found in the next section[11]:-

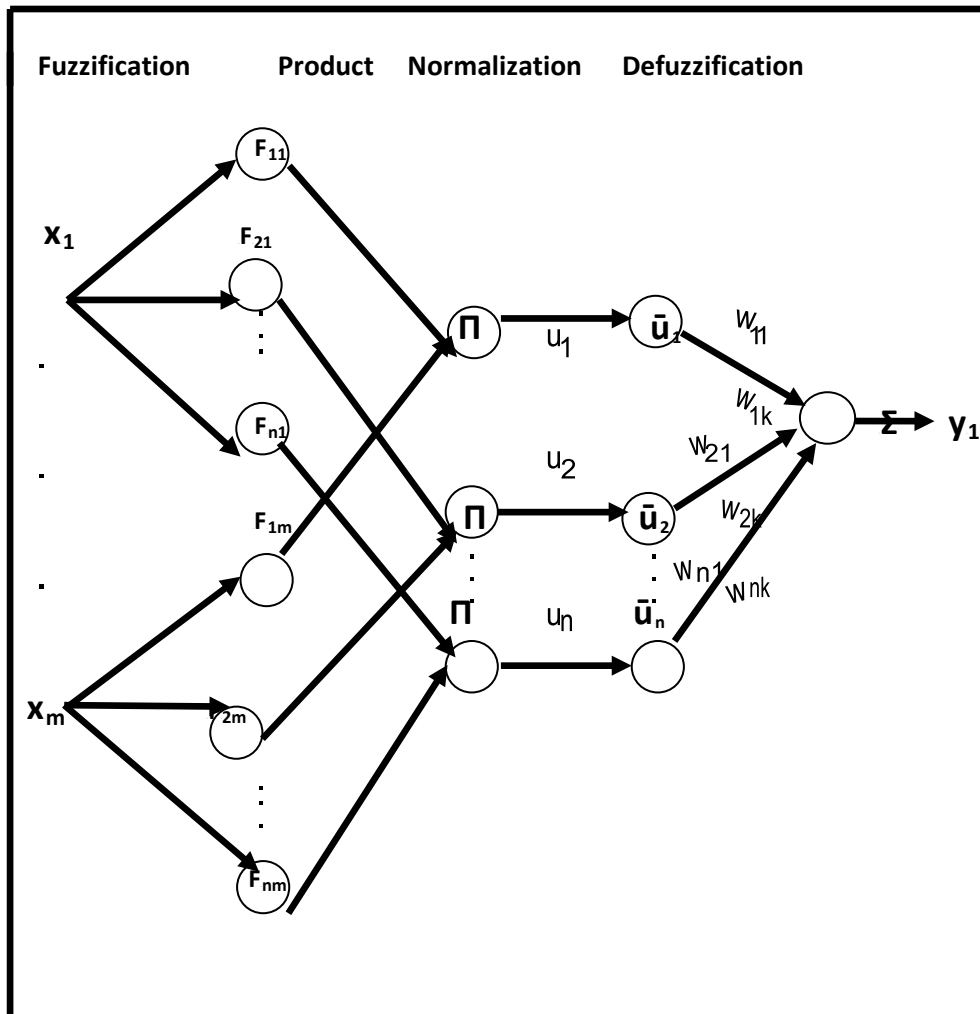


Figure 2. Structure of fuzzy neural network

In the following items , the basic function of each layer will be described:-

- 1- **Input layer** :transmits the input linguistic variables X to the output without change.
- 2- **Fuzzification layer**, membership layer represents the input values with the following Gaussian membership functions:

$$F_{ij} = e^{-\frac{1}{2} \left( \frac{x_j - c_{ij}}{s_{ij}} \right)^2} \dots\dots\dots (1.1)$$

where  $c_{ij}$  and  $s_{ij}$  ( $i=1,2,\dots,m$ ;  $j=1,2,\dots,n$ ), respectively, are the mean and standard deviation of the Gaussian function in the  $j^{\text{th}}$  term of the  $i^{\text{th}}$  input linguistic variable X to the node of this layer , where m is the number of input variable and n is the number of rules.

- 3- **Product layer**, rule layer implements the fuzzy inference mechanism, and each node in this layer multiplies the input signals and outputs the result of the product . The output of this layer is given as :

$$u_i = \prod_{j=1}^m F_{ij} \dots\dots\dots (1.2)$$

where  $u_i$  represents the  $i^{\text{th}}$  output of rule layer.

- 4- **Normalization layer** , The output ( $u_i$ ) of product layer is normalized in this layer through dividing its value by the summation of all the outputs of all rules as:

$$\bar{u}_i = u_i / \sum_{i=1}^n u_i \dots\dots\dots (1.3)$$

where n is the number of rules.

- 5- **Defuzzification layer** , the summation of all normalized values ( $\bar{u}_i$ ) is multiplied by the corresponding weight  $w_{ij}$  which represents the consequent part of the rules, to produce the center of gravity (CoG) defuzzification operation. The outputs  $y_j$  for ( $j = 1, \dots, k$ ) represent the crisp values for the given inputs which can be obtained by the following equation:

$$y_j = \frac{\sum_{i=1}^n \bar{u}_i w_{ij}}{\sum_{i=1}^n w_{ij}} \dots\dots\dots (1.4)$$

**4.Load balancing**

Load balancing aims to increase capacity and fault tolerance and high performance of networks. It is necessary to ensure the best load balancing in the all paths ad hoc network. Congestion this effect on network performance and causes delay the packets or because of nodes queue is full may be drop incoming packets, etc., this lead to search about solutions to solve or may be

reduce of the losses through applying technique load balancing in Ad hoc Network.

One of the critical issues to the performance of ad hoc network is the issue of balancing the work load of computational tasks among the different nodes comprising the system as seen in figure (3),[12].

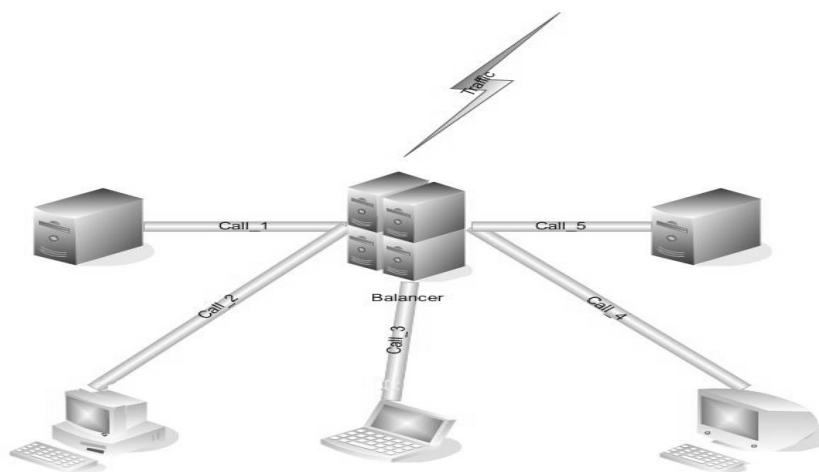


Figure 3. load balancing example

The important classification for load balancing algorithm is that **static algorithms** are the process of manually population distributed traffic to destination node, and threshold levels are fixed and do not change according to the current state of the network. This may be suitable for small networks when no redundant network links equal in metric

between source and destination, while **the dynamic algorithms** are more complex to implement because metric value in both links and nodes changing dynamically according to the current state of network. In general, dynamic load balancing algorithms can respond better to network changes and result in better performance [13].

**In the next items brief introduction of the literature review that related with our work**

### 5. Related works

**Z. Xu, K. Wang and L. Qi** [in 2009][14] presented a multi-path based on load balancing algorithm that has routing metric, which reflect the load distribution along the path. It is a simple but effective algorithm to balance the load and alleviate congestion in network. Firstly, algorithm analyzes the queuing model and puts forward two formulas to evaluating the partial function and whole function for ad hoc networks. Using the connective matrix and traffic matrix, the usage condition of every link and function index can be calculated. At last, the threshold value determined to limit the excessive usage of links, reduced the possibility of congestion. Simulation and comparisons with some typical route

algorithms show that our algorithm is robust and effective.

**P. Sivakumar and K. Swamy** [in 2011][15] proposed a new distributed load based routing algorithm intended for a variety of traffic classes to establish the best routing paths. The proposed algorithm calculates the cost metric on the basis of the load on the links. The dynamic traffic can be classified as a multimedia and normal traffic. Multimedia traffic is considered as high priority and normal traffic as low priority. The routing of high priority traffic is performed over the lightly loaded links, in such a manner that the links with lighter loads are chosen instead of links with heavier-loads. In

addition, the resources can be shared between the high priority traffic's path and low priority traffic. In the absence of multimedia traffic, the lightly loaded path can be utilized by normal traffic.

A. Alakeel [in 2012][16] displayed a new fuzzy dynamic load balancing algorithm for homogenous distributed

**6. Proposed algorithm**

The proposed algorithm used two fuzzy neural system (FNS). The first based on two input variables, queue length, and permitted queue size, the queue state is the output which combined input variable of two FNS with the throughput to specify the load of each node. This FNS is located locally at each

systems. The algorithm utilized fuzzy logic in dealing with inaccurate load information, making load distribution decisions, and maintaining overall system stability. In terms of control, he propose a new approach that specifies how, when, and by which node the load balancing is implemented. This called CBD.

node of the ad hoc network to make a load balancing for nodes using four criteria, such as, above ( queue length , permitted queue size , queue state and throughput), where h units of product and normalization layers ,consider h=20 is the number of rules in the FNN1 and h= 16 for the second one, as shown in figure (4).

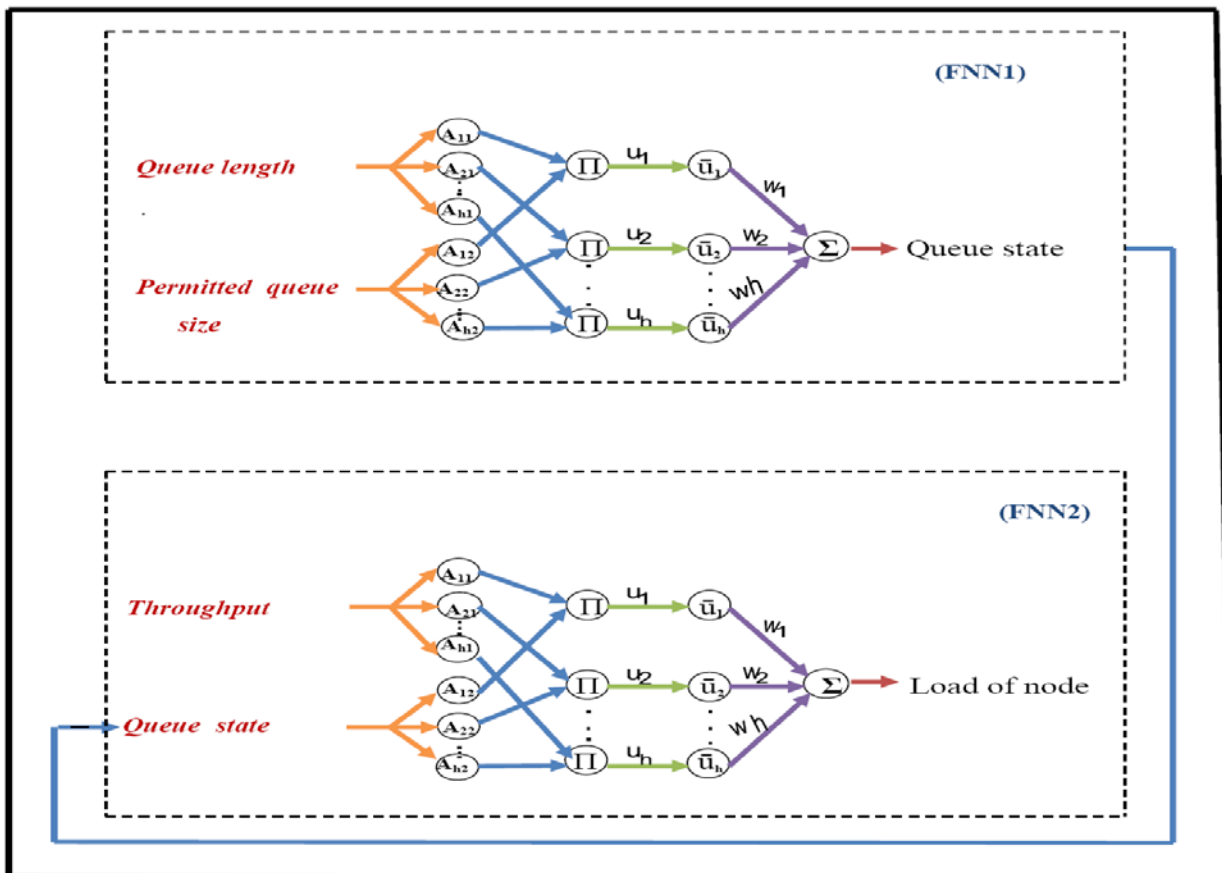


Figure 4. the fuzzy neural system

Table (1) describe the variables linguistic , the center with the value for each one the centers and linguistic variables

<i>a variables Linguistic</i>	<i>Center</i>	<i>Linguistic value</i>
<i>Queue length</i>	<i>6</i>	<i>Very short</i>
	<i>12</i>	<i>Short</i>
	<i>18</i>	<i>Medium</i>
	<i>24</i>	<i>Large</i>
	<i>30</i>	<i>Very large</i>
<i>Queue size</i>	<i>0</i>	<i>Zero</i>
	<i>0.33</i>	<i>Min- value</i>
	<i>0.66</i>	<i>Mid -value</i>
	<i>1</i>	<i>Max- value</i>
<i>Queue state</i>	<i>3</i>	<i>Under-full</i>
	<i>6</i>	<i>Mid-full</i>
	<i>9</i>	<i>Full</i>
	<i>12</i>	<i>Over-full</i>
<i>Throughput</i>	<i>10</i>	<i>Small</i>
	<i>15</i>	<i>Medium</i>
	<i>20</i>	<i>Big</i>
	<i>25</i>	<i>Very big</i>
	<i>Load of Node</i>	<i>2</i>
<i>10</i>		<i>Medium</i>
<i>18</i>		<i>Heavy</i>
<i>26</i>		<i>Very heavy</i>

**7. Simulation Results**

The simulation has been realized using C++ programming language, for evaluating the efficiency of the proposed method of using fuzzy neural system to solve the load balancing problem in ad hoc network. This simulation applied for

two examples of ad hoc networks (AN1,AN2), these are indicted in the previous section .

There are two examples of ad hoc networks used in the proposed algorithm which shown in figure (5) and figure (6).

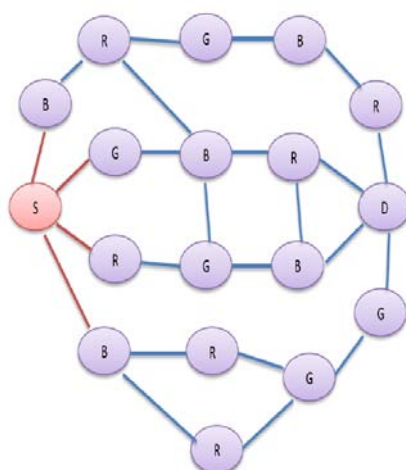


Figure (5) ad hoc network (AN2)

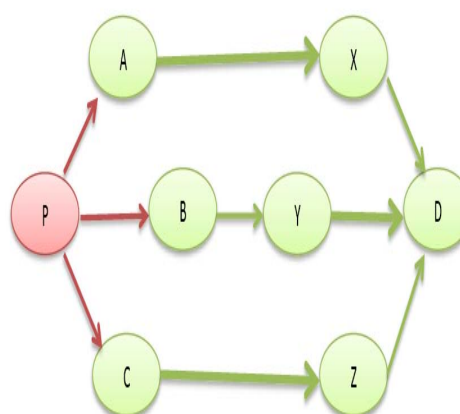


Figure (6) ad hoc network (AN1)



For example , in the ad hoc network (AN1), the proposed FNS is applied at each node connect in the network such as nodes (P ,A, B ,C ,.... ) . Let us take node (p) , there are two received inputs to apply the first FNN1, firstly, queue length in this node is very short in linguistic values of membership functions with value (10 ), also the queue size with Min value ( 0.4). Then the queue state of this node is under full with value (3.04) . After that applied the FNN2 with two input which are the output of the FNN1(queue state ) which is under full according to applying the

FNN1, with its value, and throughput for the node with value ( 11.5 ) that is small , to resulted the load of this node in the network with value of (2) is lightly, the steps are repeatedly for all nodes of network.

The proposed FNS has two fuzzy neural network , twenty units of product for FNN1 and sixteen units of product for FNN2 with normalization layers, and one output. Following steps of initialization is used to set the parameters value.[12]:-

**Step1-** For  $i = 1, \dots, h-2$ , the training sets  $(x_1(i), \dots, x_v(i), y_{01}(i), \dots, Y_{0q}(i))$  which are inputs and desired outputs are presented, where  $h$  is the number of rules,  $v$  is the number of inputs,  $q$  is the number of outputs.

**Step2-** For  $i = 1, \dots, h-2, k = 1, \dots, v, j = 1, \dots, q$ , the center  $c_{ik} = x_k(i)$ , the weight  $w_{ij} = y_{0j}(i)$ ,

For  $i = h-1$ ,

$$c_{ki} = a_k ,$$

$$w_{ij} = 1 ,$$

For  $i = h$ ,

$$c_{ik} = b_k,$$

$$w_{ij} = 1,$$

$a_k$  is the lower bound

$b_k$  is the upper bound of

**Step3-** For  $i = 1, \dots, h, k = 1, \dots, v$ , the width

$s_{ik} = \max ( |c_{ik} - c_{rk}|, |c_{ik} - c_{lk}| ) / \sqrt{|\ln \lambda_k|}$  , where  $c_{rk}$  is the center of membership function at right side for input variable  $x_k$ ,  $c_{lk}$  is the center of membership function at left side for input variable  $x_k$ , and  $\lambda_k$  is a factor,  $0 < \lambda_k < 1$

The Gaussian membership function used to perform a fuzzification operation of the proposed fuzzy neural System ( FNS) (equation (1.1)). This FNS is trained by backpropagation algorithm, when the parameters (weight, center and width) are adjusted to minimize the error function. Are used to AN1 , AN2, 15 training sets are taken. The training operation continues, until the minimum value of mean squared error is obtained. For that, some values of learning rates ( $\eta_w, \eta_c, \eta_s$ ) with value of (0.9,0.9,0.9) and momentum rates ( $\alpha_w, \alpha_c, \alpha_s$ ) with value (0.6,0.6,0.6) are employed to get best convergence which are selected by trial and error.

The testing is performed on the trained sets, and on other test sets for each of the ad hoc networks (AN1, AN2). The results of the testing are exposed in Tables (2)-(3).

Table (2) some of the test results of the FNSfor AN1

FNN1			FNN2	
Inputs		Output	Input	Output
Queue length (Kbps)	Queue (sizeKbps)	Queue state	Throughput (Kbps)	Load of Node
20	0.5	9	22	21.4595
21	0.45	9.021	23	22.5405
20	0.02	4.672	12.4	4.81655
14	0.5	3.873	19.9	9.80671
7	0.006	2.014	24	15.8182
10	0.4	3.04	11.5	2

Table (3) some of the test results of the FNS for AN2

FNN1			FNN2	
Inputs		Output	Input	Output
Queue length (Kbps)	Queue (sizeKbps)	Queue state	Throughput (Kbps)	Load of Node
17	0.23	3.2721	14	3.25215
7	0.99	9.331	23	22.5405
20	0	3.0156	21	12.1818
8.8	0.4	2.58391	13.6	2
11	0.3	3.5504	14.6	4.36105
21	0.67	9.897	24	23.8182

In AN1, for the same example that discussed above, for node (P) Queue length is (14 Kbps) and Queue size is (0.5 Kbps), the queue state for this node is (3.873), under full according to table (1) . Then the queue state enter to the FNN2 with the throughput (19.9Kbps ) to compute the load of the node which is ( 9.80671 ) , but is nearly to medium. The same

operation is applied on (P – B) and (P- C).

Also, in AN2, node(S) connected with each of nodes (B ,G, R, B) for nodes(S) ,the queue length is (11 Kbps) and Queue size is (0.3 Kbps) .The queue state is calculated (3.5504), compared with the throughput (14.6) to find the load of node (4.36105)..

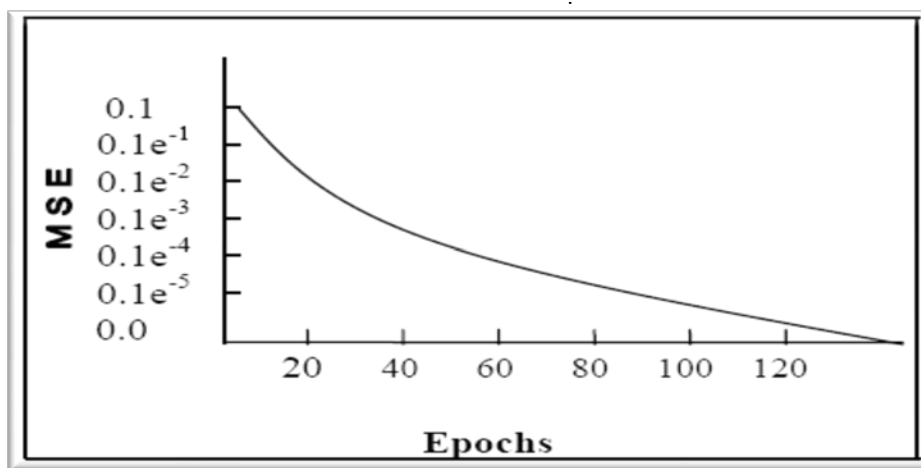


Figure (7) error versus number of epoch of the FNS for AN1

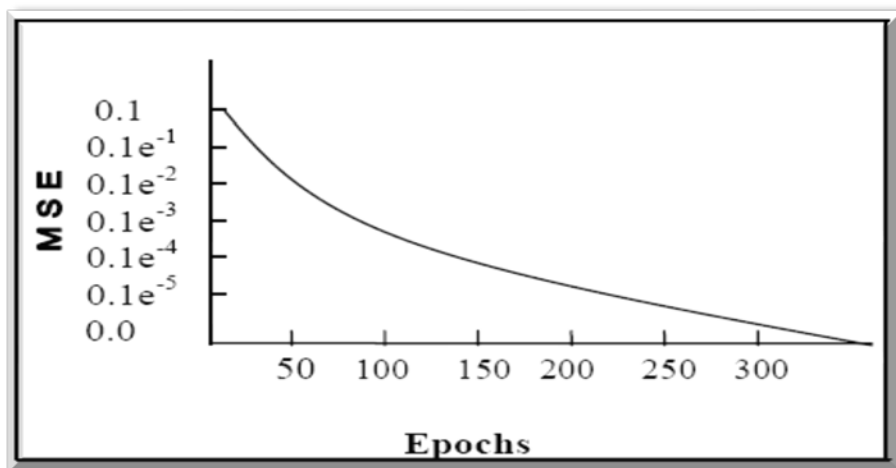


Figure (8) error versus number of epoch of the FNS for AN2

where , MSE is the mean square error .

From figures(7,8) conclude that the number of epochs for training stage of AN2 is greater than the AN1 because it's used

along number of nodes for the same error ratio.

Table (4), displays the success rates of test on non - trained sets.

Table (4) the success rates of testing theproposed fuzzy neural system (FNS) for the ad hoc network(AN1 and AN2)

Ad hoc network	Success rate of test on non-training sets)
AN1	99%
AN2	98 %

### 7- Conclusions

The proposed algorithm used tow fuzzy neural system (FNS) to solve the load balancing problem of the adhoc network which depending on (queue length , queue size, queue state and throughput) .thebackpropogation is used to train the network and testes for 2 – examples with different value of

linguistic varabiles . the number of epochs for AN2 is greater than AN1 because , its used large number of nodes which lead to more complexity . theperformance of network is better when combined the fuzzy with neural network to solve load traffic in the network.

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### موازنة حمل ديناميكي لعقد الشبكة الخاصة باستخدام شبكه عصبية مضيبه

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#### المستخلص

في شبكات الحاسبات الضخمة الكثيرة التغييرات تصل باستمرار نماذج البيانات بنسب مختلفة وفي اوقات مختلفة وهذا النسب قد تكون في ثلاث حالات (واطنه , متوسطه , عاليه ) وحيث كل نسبة بيانات تحتاج الى قابليه رابط تتناسب معها الغرض المحافظه على اداء الشبكه, وكنتيجه كون الحمل غير الموزون للبيانات المارة بين الروابط (او النقاط) يقلص من انجازية الشبكات, لذلك فان من الضروري استخدام تقنيه لتوفير موازنة حمل بين روابط (النقاط) الشبكه المؤديه الى نقطه الهدف لنماذج البيانات القادمة بحيثلا يحدث تجاوز لنسب البيانات على قابليه الروابط , لذلك فان موازنة الحمل تعتبر مسألة ضرورية جدا".

في هذا البحث، اقترح نظاما يستند على المنطق المضيب والشبكات العصبية (FNN) لحل مسألة موازنة الحمل في شبكات الخاصة وتحقيق حمل ديناميكي والذي يواجه تغييرات الشبكه المستمره. يقع النظام المقترح في كل عقد شبكة الادهوك ليصنع موازنة حمل للعقد باستخدام اثنين من الشبكات العصبية المضيبه , تعتمد الاولى على قياسين هما : طول الطابور والحجم المسموح للطابور لينتج حاله الطابور ( فارغ ... ممتلئ ) . و تعتمد الثانيه على استخدام قياسين الاول هو حاله الطابور والذي يمثل اخراج الشبكه العصبية الاولى والثاني هو انجازيه العقد وبالتالي بحسب مقدار الحمل على هذه العقده.

طبق التدريب والفحص لهذا النظام لنموذجين من شبكات الادهوك حيث اكدت نتائج هذا النظام العصبية المضيب على انجازيته العاليه.

الكلمات المفتاحيه : الشبكات الخاصه , موازنة الحمل , المنطق المضيب , الشبكات العصبية