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# Development of Fuzzy Based Detection of Link Failure in Overlay Network

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**Abstract** - Performance of overlay networks can be improved if proper detection of link failures is done and deployment of overlay nodes in exact locations are done. The major factors that result in link failure are loss of signals, loss of synchronization, link capacity and faulty interfaces. Though extensive research is carried out in improving the performance of overlay networks, intelligent identification of the exact location of link failure is still unsolved. In this paper a Fuzzy Logic based inference system has been proposed to identify the probability of link failures. It is found that Fuzzy based system provides better results irrespective of the membership functions for this particular application and the location of link failures has been successfully identified**.**

**Keywords:** *Fuzzy logic; overlay network; FIS; membership functions; fuzzification; defuzzification.*

## I. INTRODUCTION

Network protection against faults and errors is an important problem. Of the various faults, such as link failure, congestion, packet loss etc, link failure is one of the major factors as it the performance of network. Link failure occurs due to various parameters in which some can be rectified within few seconds, some within few minutes and some that can't be rectified which in turn reduces the network performance. Major reasons for link failure in the communication link between the two or more users are due to limited link capacity, signal loss, design of router architecture along with routing dynamics, equipment problem, denial of service, loss of synchronization and faulty interface [2], [3] and [4]. Though extensive research is carried out in this area to provide protection over link failures [1], identifying link failure is itself a major area of concern. This paper proposes an intelligent method for the detection of link failure based on Fuzzy logic.

Fuzzy logic is basically a rule based system that is best suited for finding solutions in non-linear systems. It applies the rules on the input parameter and gives the output parameter based on the input i.e. it executes the output based on the rules framed by the user depending on the input parameters. In this paper, fuzzy rules are generated with four distinct input parameters namely loss of signal, loss of synchronization, faulty interface and link capacity.

The outcome of this rule base decides the exact link that has the maximum probability of failure.

In this paper, section III gives the overview of a basic fuzzy logic system. Parameters that result in the link failure are analyzed and summarized in section IV. Framing the rules and the methodology is described in the section V. Results and the discussion are quoted in section VI. Thus, section VII concludes the paper with a conclusion.

## II. RELATED WORK

Srihari et al (2007) proposed a local rerouting based approach called Failure Insensitive Routing (FIR) that uses the interface-specific forwarding against the failures and if failure occurs they suppress the link state advertisement and they triggers the rerouting using the back warding table instead of the failure. They presented an algorithm for computing the interface-specific forwarding and backwarding tables to handle the single link suppression and the correctness that ensures the delivery of packets to the destination along the loop-free paths is proved. The concept of FIR is, when the link failure is occurred the adjacent node suppresses the global advertisement that initiates local rerouting for forwarding the packets to the destination [2].

Gianluca et al (2002) investigated the occurrence of failures in Sprint's IP backbone and their potential impact on emerging services such as Voice-over IP (VoIP). The three different points in Sprint IP backbone is derived from the IS-IS routing updates. They also discussed various statistics such as the distribution of inter-failure time, distribution of link failure durations, etc. that is essential for constructing a realistic link failure model. They also presented an analysis of routing and service convergence time during a controlled link failure scenario. Their results indicate that rerouting the packets after link failure is not only depend on routing protocol dynamics, but also on the design of router's architecture and control planes. Thus they offer their views into two basic components for defining network-wide availability, which is considered as a more appropriate metric for service-level agreements that supports the emerging applications [3].

Kamal et al (2011) introduced a resource efficient and fast method for providing the network coding protection scheme against single and multiple link failures. They made sure that in a connection, each node receives two copies of the same data unit. One copy was given to the working circuit and the second copy extracted from linear combinations of data units transmitted on a shared protection path. This guaranteed instantaneous recovery of data units upon a failure of a working circuit. It required fewer protection resources and a simpler synchronization strategy had been implemented. This strategy was implemented in an overlay layer which makes it deployment simple and scalable [4].

Amit et al (2010) used a special propagation mechanism which propagates a unique kind of parallel route discovery for real time scenario to send the time critical data safely. They used a temporal parallel route recovery scheme that builds a temporary path between the nodes during the link failure. The important node then forwards the buffered packets to the destination without any loss. They also compared these extensive models with the standard models performance metrics such as packet delivery ration, routing overheads and average delay that are analyzed [5].

Emmert et al (2006) provided a novel approach in order to ensure sustainable operations over distributed systems. It was accomplished by using peer-to-peer overlay networks. They showed the process of detection and localization of the causes for link failures using maintenance traffic of P2P overlay networks. Their results had reduced installation costs and traffic overhead for network monitoring architecture [6]. From the literatures, it is found that intelligent detection of link failures will result in better performance of overlay nodes.

## III. OVERVIEW OF FUZZY LOGIC

Fuzzy set is an extension of a crisp set which poses the ability as a human mind to effectively employ the modes of reasoning that are to be approximate rather than exact [5]. The nonlinear functions of arbitrary complexity to a desired degree of accuracy can be modeled using the Fuzzy Logic. It is the tool that can map multi-input space to the multi-output space of a system. With a Fuzzy Logic, one can specify the relationship between the input and output parameters in terms of words rather than numbers using IF-THEN rules. In addition, Fuzzy sets also allow the partial membership function along with the full or no membership function.

In Fuzzy set theory, set A on a universe of discourse U is characterized by a membership function $\mu_A(x)$ that takes values in the interval [0, 1]. Fuzzy sets represent commonsense linguistic labels like slow, fast, small, large, heavy, low, medium, high, tall, etc. Various types of membership functions are used, including triangular, trapezoidal, generalized bell shaped, Gaussian curves, polynomial curves, and sigmoid functions. Triangular curves depend on three parameters a, b and c [5] and are given by

$$f(x;a,b,c) = \begin{cases} 0, & for\ x < a \\ \frac{x-a}{b-a}, & for\ a \leq x < b \\ \frac{c-x}{c-b}, & for\ b \leq x \leq c \\ 0, & for\ x > c \end{cases} \quad (1)$$

Gaussian curves depend on two parameters σ and c and are represented [5] by

$$f(x;\sigma,c) = \exp\left[\frac{-(x-c)^2}{2\sigma^2}\right] \quad (2)$$

A Fuzzy Inference system (FIS) defines a nonlinear mapping of the input data vector into a scalar output, using Fuzzy rules [6]. The mapping process involves input/output membership functions, FIS operators, Fuzzy if-then rules, aggregation of output sets, and defuzzification. The input for the defuzzification process is the aggregated output of the fuzzy set, and the output of the defuzzification process is a crisp value obtained by using some defuzzification method such as centroid, height or maximum.

## IV. PARAMETERS RESULTING IN LINK FAILURE

Data communication is adversely affected due to link failure in the network. This link failure occurs due to many realistic reasons that include the lack of maintenance and accidental

power cuts of the network which can be recovered within small time. Loss of signals sent by the transmitter to the destination is one of the major reasons for link failure. For example in the worst case scenario if the header packet indicating the packet arrival is lost, it causes a serious damage as link establishment itself will not be done between the sender and the receiver. The lack of synchronization time interval between the users may also result in link failure due to time out. During transmission, if the desired capacity is greater than the actual designed capacities of node and link then packet drops occur indicating link failure.
In other way, the congestion in the link also leads to link failure with the overloading of packets in the single link. The configuration change of the user without the signal will lead to loss of service from the link indicated as denial of service. The interface of the third user in between the communication of two users without a proper acknowledgement fails the link because of the faulty interface.

## V. METHODOLOGY

An FIS is developed for determining the probability of link failure. In this work, link capacity, signal loss, synchronization loss and faulty interface are considered as input parameters as they can be easily quantified and link failure is regarded as the output parameter. Mamdani Fuzzy Inference System is chosen in which regardless of whether minimum or product inference is used, the fuzzy inference process essentially defines the mapping of the given vector of crisp values to an output crisp value using fuzzy rules stored in the knowledge base. Defuzzification is done with centroid method that works on the aggregated input and results in the crisp value used for the mapping process.

Each of the four inputs has seven membership functions indicating the probability of occurrence. The link capacity and loss of signal has the membership functions namely very low, small medium, medium, large medium, high, very high and very minimum, minimum, small middle, middle, large middle, maximum, very maximum respectively. Very lesser, lesser, low normal, normal, high normal, greater, very greater and very small, small, low mean, mean, high mean, more, very more are the respective membership functions of synchronization loss and faulty interface. The ranges given for input parameters are 0-0.2, 0.1-0.3, 0.2-0.4, 0.3- 0.5, 0.4- 0.6, 0.55-0.79 and 0.7-0.9. In the same way the output Link failure is ranged as 0-0.24, 0.1-0.34, 0.18-0.4, 0.23-0.7, 0.4-0.8 and 0.5-0.97. The proposed Fuzzy Inference System is as shown in Figure 1.

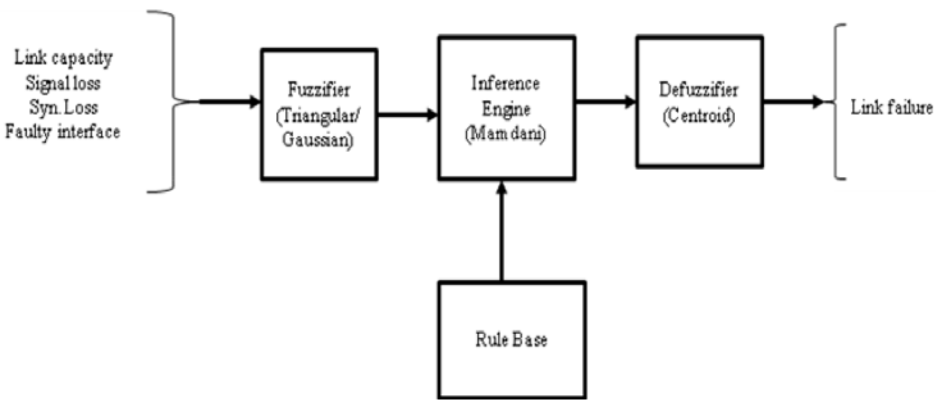


Figure 1: Block Diagram of Deployed Fuzzy Inference System

The membership function types can be triangular, trapezoidal, generalized bell shaped, Gaussian curves, polynomial curves, and sigmoid functions. The Triangular and Gaussian curves are the two membership function evaluated in this work. Rule editor is used to frame the rules for processing the input and detecting the link failure as output. IF-THEN rules with "AND" implication is used for comparing the inputs membership functions with each other based on the probability values for detecting the link failure. Of a total of 187 rules, few rules are listed below to indicate the impact of the input parameters for determining the probability of link failure. Higher the crisp value, the link is more probable to fail.

- If (linkcapacity is v.low) and (signalloss is v.min) and (loss_syn is v.lesser) and (facilityinter is v.small) then (output1 is avg) (1)
- If (linkcapacity is v.low) and (signalloss is min) and (loss_syn is lesser) and (facilityinter is small) then (output1 is avg) (1)
- If (linkcapacity is v.low) and (signalloss is large.mid) and (loss_syn is h.normal) and (facilityinter is h.mean) then (output1 is good) (1)
- If (linkcapacity is low) and (signalloss is v.min) and (loss_syn is v.lesser) and (facilityinter is v.small) then (output1 is avg) (1)
- If (linkcapacity is small.med) and (signalloss is v.min) and (loss_syn is v.lesser) and (facilityinter is v.small) then (output1 is avg) (1)
- If (linkcapacity is med) and (signalloss is v.min) and (loss_syn is v.lesser) and (facilityinter is v.small) then (output1 is avg) (1)
- If (linkcapacity is large.med) and (signalloss is small.mid) and (loss_syn is low.normal) and (facilityinter is low.mean) then (output1 is avg) (1)
- If (linkcapacity is high) and (signalloss is min) and (loss_syn is lesser) and (facilityinter is small) then (output1 is better) (1)
- If (linkcapacity is v.high) and (signalloss is max) and (loss_syn is greater) and (facilityinter is more) then (output1 is good) (1)
- If (linkcapacity is large.med) and (signalloss is v.min) and (loss_syn is h.normal) and (facilityinter is h.mean) then (output1 is less) (1)

## VI. RESULTS AND DISCUSSION

A Mamdani Fuzzy inference system as shown in Fig.1 was simulated using Matlab FIS editor. 186 rules were framed using the rule editor. Two different membership functions namely triangular and Gaussian were chosen for fuzzification. The defuzzification method chosen is centroid. After executing the simulator, the performance of the simulator was studied separately for triangular and Gaussian membership functions. The relationship between the input parameters and the output parameter for triangular and Gaussian membership functions as surface graphs are shown in Figures 2-5. In the surface graph, blue indicates high risk of link failure while green indicates medium risk. A safer link is indicated by yellow.

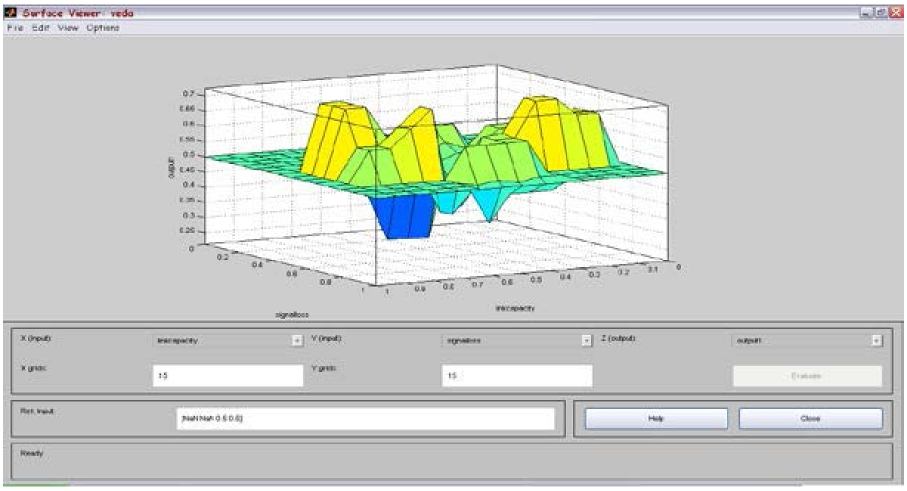

Figure 2: Surface View of Link Capacity and Signal Loss for Triangular Function.

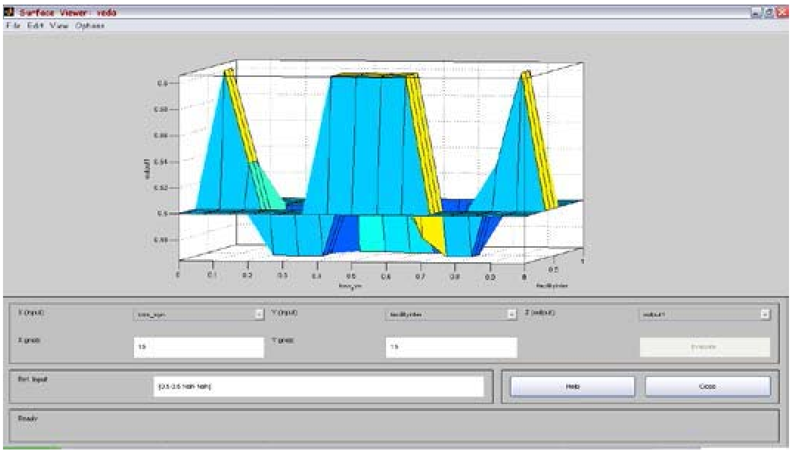

Figure. 3: Surface View of Synchronization Loss and Faulty Interface for Triangular Function

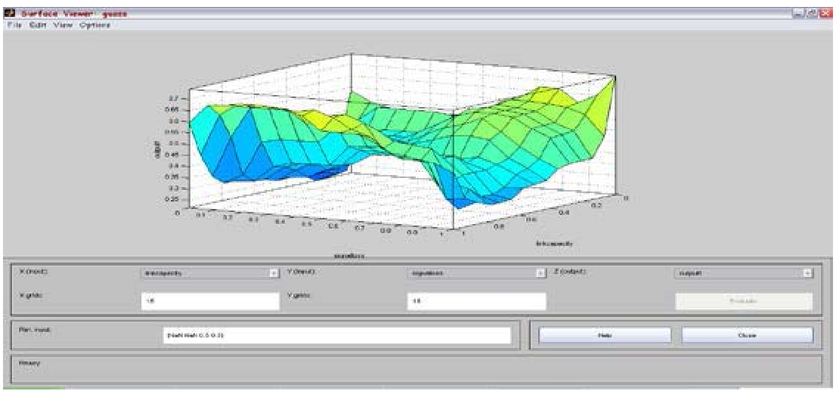

Figure. 4: Surface View of Link Capacity and Signal Loss for Gaussian Function.

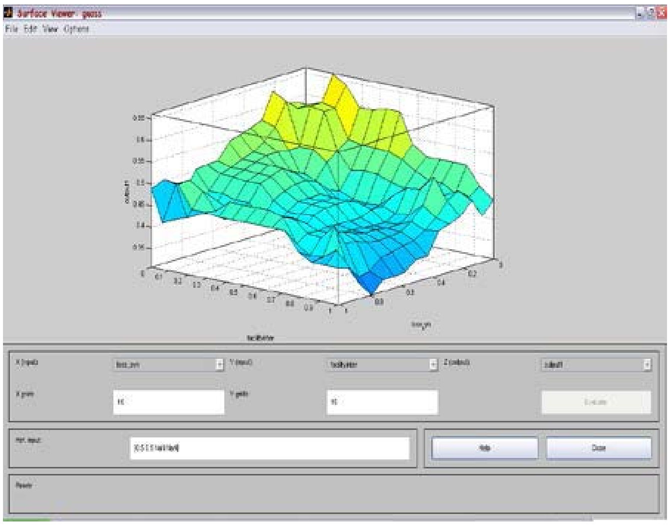

Figure. 5: Surface View of Synchronization Loss and Faulty Interface for Gaussian Function.

After detecting the link failure using the fuzzy the link that has low value and chances to fail is failed in the network that is simulated and the corresponding results are analyzed. Then the simulator was used for determining the probability of link failure for a set of crisp values and is shown in Table 1. It is found that for this particular application irrespective of the membership functions, the probability of link failure is nearer to the actual values. Once the probability of the nodes is determined, decision is made on the status of that particular link in the overlay network. If the probability of link failure is greater, that particular link is deliberately failed in the overlay network and the performance is analyzed.

Table -1 Fuzzy Based Analyzed Values for the Input Parameters Using the Rule Editor:

| S.NO | INPUT PARAMETERS | | | | OUTPUT PARAMETER | |
|---|---|---|---|---|---|---|
| | LINK CAP | SIG LOSS | SYN LOSS | F.INTERFACE | LINK FAILURE | |
| | | | | | TRIANGULAR FN | GAUSSIAN FN |
| 1. | 0.1 | 0.1 | 0.1 | 0.1 | 0.497 | 0.467 |
| 2. | 0.2 | 0.2 | 0.2 | 0.2 | 0.51 | 0.492 |
| 3. | 0.3 | 0.3 | 0.3 | 0.3 | 0.538 | 0.454 |
| 4. | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.493 |
| 5. | 0.5 | 0.5 | 0.5 | 0.5 | 0.509 | 0.451 |
| 6. | 0.6 | 0.6 | 0.6 | 0.6 | 0.552 | 0.442 |
| 7. | 0.7 | 0.7 | 0.7 | 0.7 | 0.469 | 0.459 |
| 8. | 0.8 | 0.8 | 0.8 | 0.8 | 0.606 | 0.397 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 9. | 0.9 | 0.9 | 0.9 | 0.9 | 0.5 | 0.315 |
| 10. | 0.5 | 0.1 | 0.8 | 0.6 | 0.51 | 0.306 |
| 11. | 0.2 | 0.4 | 0.6 | 0.8 | 0.5 | 0.538 |
| 12. | 0.3 | 0.5 | 0.7 | 0.9 | 0.509 | 0.425 |
| 13. | 1.0 | 0.7 | 0.3 | 0.2 | 0.5 | 0.685 |
| 14. | 1.0 | 0.2 | 0.9 | 0.3 | 0.514 | 0.415 |
| 15. | 0.7 | 0.5 | 0.9 | 0.1 | 0.5 | 0.402 |

## VII. CONCLUSION

The key aspect in overlay nodes lies in the detection of link failures. In this paper an effective Fuzzy based link failure detection system has been proposed and executed. It is found the proposed system is less vulnerable to the type of the membership functions and provides better results in both the cases. However in this work, only link failure detection has been done. The future work aims at analyzing the performance of the overlay network by deliberately failing the identified link and determining the throughput and loss rate. Also in this work only four input parameters are considered. However the performance of the proposed system can be improved if all the physical parameters responsible for link failure are considered and analyzed.

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