An Adaptive Fault tolerant Moblie Adhoc Network using Fuzzy Paraconsistent Logic

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Abstract **To construct a reliable mobile adhoc network one of the important design issue is Fault-tolerance. Due to the link failure, node failure, misbehaving nodes, network failure, power and energy consumption many types of faults may occur in mobile network. Numerous existing designs of ad hoc networks are based on the idea of non-adversarial environments, in which each node in the network is supportive and well-mannered. Several fuzzy logic based shortest route selection algorithms are developed but they failed to handle the contradiction rules are generated by inference system. It results in selection of incorrect path selection, which doesn't able to handle the fault occurrence. The proposed work has the ability to accept the contradiction occurred among the generated rules for path selection and it treats them as a special case with the help of multi-valued logic termed as paraconsistent logic which contributes for selection of shortest route in case of faults.**

Keywords: Fault Tolerance ,Fuzzy Paraconsistent, Inference System, Contradiction

I. INTRODUCTION

Fault tolerance is a significant property of MANETs .It is the ability of a system to deliver a desired level of functions even in the presence of faults an also to improve the system reliability. It also used to prevent the malfunctioning node. Since the sensor nodes are prone to failure ,fault tolerance should be seriously considered in many sensor network application.

Different types faults are as follows:

Fault due to Node Failures

Fault due to Link failure and Network Failure

Fault due to Transmission Power and Energy

Fault using check-pointing, message logging, reducing overload etc.

The well-known MANET routing algorithms (e.g., DSR, multipath routing like AOMDV) are unsuitable as fault-tolerant routing algorithms for MANETs. Since DSR chooses the shortest path route for packet transmission in adversarial environments, it can be shown that DSR will achieve a low packet delivery rate. On the other hand, multipath routing algorithms like AOMDV are strong in their fault-tolerance ability, because they send multiple copies of packets through all possible (disjoint) routes between a pair of source-destination nodes. However, the disadvantage with multipath routing algorithms is that they introduce an unnecessary amount of overhead on the network. Without a mechanism that ―tolerates‖ route failures due to malfunctioning nodes while making routing decisions, the performance of ad hoc network protocols will necessarily be poor, and the routing decisions made by those protocols would be erroneous

Problem Definition

Designing routing protocols poses further challenges when one needs to design routing schemes in the presence of adversarial environments in MANET networks. The need for fault tolerant routing protocols was identified to address routing in adversarial environments, specifically in the presence of faulty nodes, by exploring network redundancies[2][3]. This paper discusses fault-tolerant routing schemes [4] where there are malfunctioning nodes in the network. Different routing mechanisms have been proposed in the literature for MANETs primarily, those that work under the assumption of ideally behaving environments.

This proposed work aims at developing a promising fault tolerance scheme based on multi-valued logic known as paraconsistency which handles the problem of contradiction in selection of fault tolerance based routing scheme.

Uncertainty evaluation system must follow the criteria mentioned below when choosing a path:

- The system must be able to generate results which allow a good interpretation.
- System must be able to deal with imprecision.
- System enable to calculate of uncertain value.
- It must able to supply consistent results.

- Able to present good computability of the data involved.

II. Related Work

Rana E. Ahmed [5] proposed a new fault-tolerant routing protocol (extension of Dynamic Source Routing - DSR) that attempts to find two routing paths, if exists from the source node to the destination node. This method produced low-overhead in terms of control messages and the message sizes. Disadvantage is RREP (Route Reply) message has more information (for both primary and secondary paths) to carry, while basic DSR carries information about primary path only. When compared to the classical DSR protocol, the proposed method achieved an output with higher packet delivery ratio, higher network throughput, and less control message overhead.

Jayalakshmi and Ramesh kumar [6] proposed an energy efficient multipath fault tolerant routing protocol to improve the reliability of data routing in Mobile ad hoc networks. This multipath routing protocol modified the route discovery and route maintenance mechanisms of DSR and Ad hoc On-Demand Distance Vector (AODV) protocols to improve the performance of a network in terms of delay, reliability, overhead reduction, energy efficiency and network throughput.

Rajesh Kumar [7] attempted to reduce the route breakages and congestion losses. The Ad hoc On-demand Multipath Distance Vector (AOMDV) protocol is used as a base for the multipath routing. More nodes are enabled for recovering a dropped packet. Proactively detects node level and link level congestion and performs congestion control using the fault-tolerant multiple paths. The proposed protocol achieves better throughput, packet delivery ratio with reduced delay, and packet drop energy.

Rajkumar [8] presented an Improved Fault Tolerant Multipath Routing (IFTMR) protocol to reduce time delay in mobile ad-hoc networks. The strength of the path through which data or packets are transmitted and the power level of nodes are examined. The proposed method aimed in reducing the time delay.

Pooja et al [9] suggested Enhancement of Multipath Routing Protocol for Route Recovery (EMPRR) in MANET, which provides multipath discovery, efficient utilization of bandwidth and controlled traffic load route recovery at the time of failure. The proposed protocol overcomes the problem of stale routes in multipath routing protocols and significant improvement in packet delivery ratio and reduced end to end delay.

Manickam et al [10] designed a new AODVEBR (Ad hoc on demand distance vector Energy based routing protocol) which optimizes AODV by creating a new route for routing the data packets in the active communication of the network. The proposed protocol efficiently managed the energy weakness node and delivered the packets to destination with minimum number of packets dropped. Reduced the control overhead and efficiently utilized the existing control packets and routing table.

Nilima et al [11] proposed a Node disjoint minimum interference multi-path (ND-MIM) routing protocol for MANETs, based on AODV protocol. Goal was to determine all node-disjoint routes from source to destination with minimum routing overhead by taking into account the energy and distance of intermediate nodes in the path. When the route is broken, the data is transmitted continuously through next shortest route.

Sudip et al [12] presented a fault tolerant routing algorithm (FTAR), based on the idea of searching the natural ants, applied the (Ant Colony Optimization) ACO on the set of paths obtained by the source routing algorithm. The ants worked on the paths which are already at the disposal of the source node. This algorithm achieved high packet delivery ratio and throughput.

Roie et al [13] developed Octopus, a fault tolerant and efficient position-based routing protocol. This protocol achieved fault tolerance through redundancy and low location update overhead obtained by using a novel aggregation technique, whereby a single packet updates the location of many nodes and thus reduced the overhead.

Fard et al. [14] have proposed an end-to-end threshold based algorithm that improves congestion control to address link failure loss in MANET. Their algorithm holds two phase. Yi et al. [15] developed the Multipath Optimized Link State Routing (MP-OLSR) protocol .The multipath is obtained using multipath dijkstra algorithm. This algorithm gains great flexibility and extensibility by employing different link metrics and cost functions. Liu and Liu [16] have designed a delay-aware multipath source routing (DMSR) protocol to offer end-to-end delay requirement in wireless ad hoc networks.

III. Methodology

Hillbut'sProgramme&Codel'sTherom

Paraconsistent mathematics says that contradiction may be true,

$A \& \neg A = \text{True}$

Example: Theory : T Statement : G

G: G cannot be provided in the theory T.

If this statement is true, then there is atleast one improvable sentence in T, making T incomplete. Else if G can be proved in T, there is a contradiction: G is provable, but by its content can also not be proven. There is a dictionary between incompleteness & inconsistence.

Rusell's Paradox

If logic is Paraconsistent the mathematics built on this logic will be paraconsistent. This statement is false. To be true, the statement has to be false and Vice Versa.

Explosive logic

If contradiction can exist, Suppose that somewhere contradiction is hiding in the theory can be identifiable using paraconsistent logic.

Classical: If A or B is true & it can be proved A is false, B in true then

Paraconsistency

If A and not A is a contradiction, the B cannot be validly deduced. We cannot receive any information about the truth of B from the fact A is not true, because it might also be true this satisfying the disjunction.[A sen J,O] = Proved = Truth values.

Paraconsistent Logic

Among the number of ideas in non-classical logic, a family of logics has been developed having as its main fundamental the principle of the excluded third, which was named paraconsistent logic.

Therefore, paraconsistent logic is a non-classical logic which revokes the principle of non – contradiction and admits the treatment of contra-dictionary signals in its theoretical structures.

Algebric Interpretation

Paraconsistent Annotated logic is framed in proportional formulas which are accomplished by annotations. In its representations each annotation belongs to τ and attributes values to its corresponding proportional formula.

Favorable degree of Evidence = μ.

Unfavorable degree of evidence = λ.

T(inconsistent), ⊥(Paracomplete or Indeterminate), F (false) and the letter t (true)

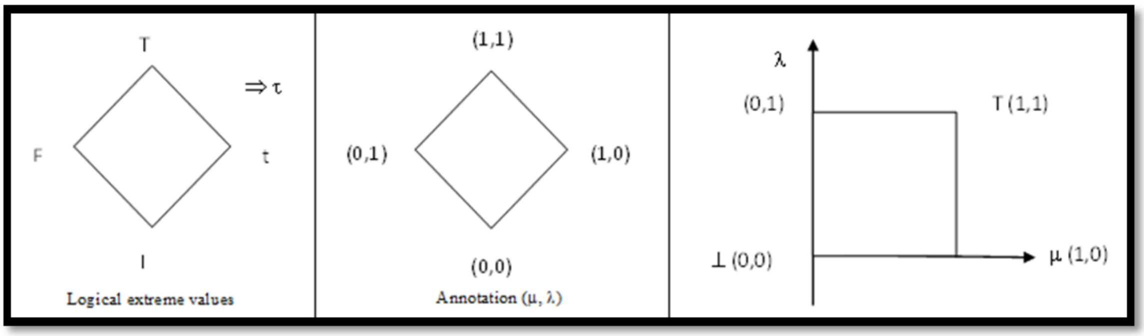

Figure 1: Paraconsistent Annotated Logic

Unitary square on the Cartesian plane (USCP)

Initially, a Cartesian coordinate, system for the plane is adopted and thus the annotation of a given proposition will be represented by points in the plane. The Unitary square on the Cartesian plane is represented as lattice τ with the co-ordinate as in Fig 2.The values of favorable degree of evidence μ are displayed on x-axis and the values of unfavorable degree of evidence λ on y-axis for each coordinate system the annotations for τ(favorable degree of evidence μ, Unfavorable degree of evidence λ) are identified with different points in the plane.

Thus, we associate T to (1,1), ⊥ to (0,0), F to (0,1) & t to (1,0)

Algebraic resolution between the user and PAL2V lattice,

Lattice £, we may associate, T⇒ (0,1), ⊥⇒ (0, -1), F ⇒ (-1,0)

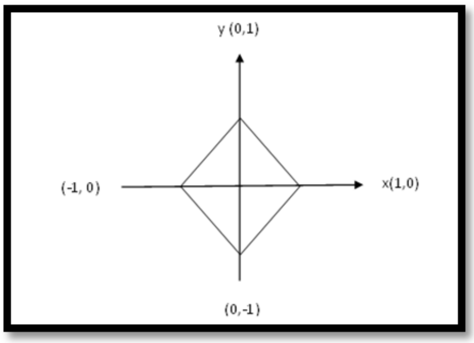

Figure 2: Unitary Square on the Cartesian Plane

£: Lattice τ in a new coordinate system

Degree of certainty D_c and the Degree of contradiction, $D_{ct.}$

$$T(x,y) = T(\mu,\lambda)$$

$$x\text{-}y = \mu - \lambda$$

It is known as degree of certain Dc and it is obtained by,

$$D_c = \mu - \lambda$$

μ =Favorable degree of evidence

λ = Unfavorable degree of evidence

$D_c \Rightarrow$belongs to the $\Re$.

The values lie between +1 & -1, in the horizontal axis of the lattice and it is known as degree of certainty Axis.

Paraconsistent Logic is an uncertain knowledge treatment. The area of AI, to construct control or experts systems that make decisions by observe the environment, one must investigate real world phenomena.The pieces of information extracted from these investigations will be use to make prediction about their behaviors and thus the systems are determined to verify the truth or falsehood of the premises. When control systems are forced to describe real-world situations, due to a number of factors call the information needed for the analysis come impregnated with noise which give them a certain degree of uncertainty. In this analysis carried out, based on information obtain in non-ideal conditions, we say that the system deals with uncertain knowledge. So, it is determined as Uncertain knowledge as the one which is debatable. The characteristics of an evident logic are suitable for literating uncertain knowledge mainly because, in an analysis, the argumentations are restrained to assert that the premises constitute only partial evidences for their conclusion is considered to make the analysis.

$D_c = +1 \Rightarrow$ means the resulting logical state of the paraconsistent analysis in True.

$D_c = -1 \Rightarrow$ it means that the resulting logical state of the analysis is false.

$$x + y - 1 = \mu + \lambda - 1$$

Degree of contradiction:

$D_{ct} = \mu + \lambda - 1$

μ = favorable degree of evidence.

λ =unfavorable degree of evidence

D_{ct} interval value lies between [+1 & -1] & are in the vertical axis and it is called as Degree of contradiction Axis.

$D_{ct} = +1 \Rightarrow$ it means that the resulting logical state of the paraconsistent analysis is Inconsistent.

$D_{ct} = -1 \Rightarrow$ it means that the resulting logical state of the paraconsistent analysis is Indeterminate.

Paraconsistent logic $T(x,y) = (\mu - \lambda, \mu + \lambda + 1)$

μ = may vary from 0 to 1,λ = may vary from 0 to 1.

Table 1 : Degree of contradiction

μ	λ	D_c	D_{ct}
0	0	0-0=0	0+0-1=-1
0	1	0-1=-1	0+1-1=0
1	0	1-0=+1	1+0-1=0
1	1	1-1=0	1+1-1=+1

Para- Analyzer Algorithm Application

In paraconsistent analysis system, the attributes of values to favorable & unfavorable degree of evidence aim at supplying an answer to the problem of contradictory signals. This is done by collections evidences and by analysis using the Para–analyzer algorithm. The system will try to change its behavior so that the intensity of the contraction diminishes.

As the favorable & unfavorable degrees of evidence values vary between 0.0 & 1.0 we may get the values of the degrees of contradiction & of certainty as an answer at anytime. It is possible to know the certainty about the proposition and if there is contradiction or not through the extract of the values considered as output.

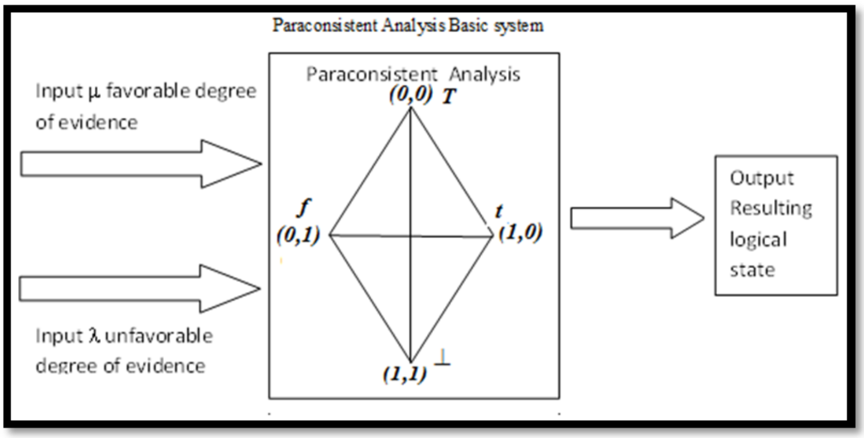

Figure 3: Paraconsistent Analysis Basic System

Three Phases:-

Phase 1: The system receives true information.

Generally these values come from sensor or from experts where the values undirected a normalization process, therefore

The pieces of information are two independent and variable values:

a) The favorable degree of evidence, which is a real value between 0.0 & 1.0
b) The unfavorable degree of evidence, which is a real value ranges between [1.0& 0.0].

Phase 2:Utilizing the equation.

c) $D_{ct} = \mu + \lambda - 1$ ⟶ to find the degree of contradiction value.

d) $D_c = \mu + \lambda$ ⟶ to find the degree of uncertainty value.

Phase 3:The system concludes

a) If there is a high degree of contradiction then there is no certainty about the decision therefore new evidences must be reached.
b) If there is a low degree of contradiction then we can formulate a conclusion, once there is a high degree of certainty.

High degree of certainty and contradiction may be positive or negative, that is these values can be considered in the systems and the limits that define what high or low is a decision that depends exclusiveness on the limit values established by external adjustments.

Proposed Methodology of Paraconsistent Fuzzy Logic for Optimal Fault Tolerance Based Route Selection :

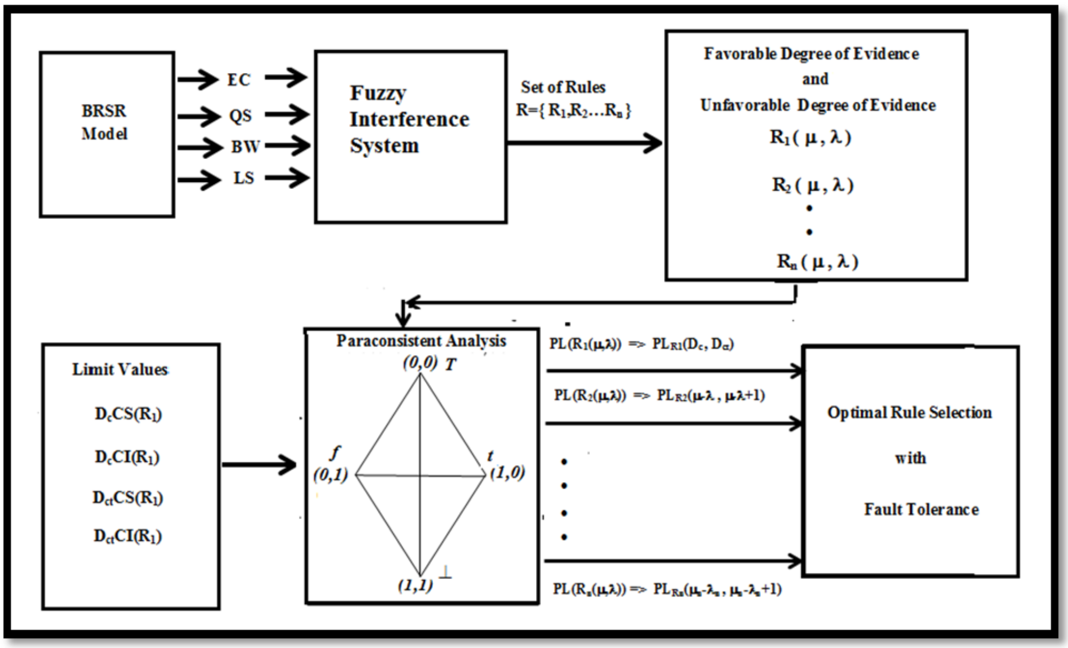

Figure 4: Overall functional flow of the proposed Paraconsistent Fuzzy inference based optimal route selection incase of fault tolerance

This proposed work utilizes the four main parameters as input to the fuzzy inference system namely Energy Consumption (EC), Queue Size (QS), Bandwidth (BW) and Link Stability. Each parameter is obtained from our previous work and model Balanced Reliable Shortest Routing (BRSR) in Ad Hoc On-Demand Multipath Distance Vector Routing Protocol (AOMDV). As an extension of previous work this paper put forth the problem of fault tolerance while selecting reliable shortest path. Based on the input parameter values the fuzzy inference system generates set of rules say R={R1, R2,R3,…Rn). Each rule has the degree of membership where it is supposed to fail in near future due to link failure. The obtained fuzzy rules cannot be accepted unless it is optimized from contradictory. To overcome this we devised a paraconsistent logic based rule optimization by determining the contradictory rules and provide special attention to the path selection strategy. The inputs to the paraconsistent Analysis is favorable degree of evidence μ and unfavorable degree of evidence λ along with its limit values control superior and control inferior for degree of certainty and degree of contradiction annotated as V_{ccs}, $V_{cci,}V_{ctcs \text{ and }}V_{ctci}$respectively.

The resultant output produced by the paraconsistent analyzer is

- If there is a high degree of contradiction on a rule then there is no certainty about the rule so it must be eliminated from the set of rules R.
- If there is a low degree of contradiction on a rule then it can be concluded that there is a high degree of certainty and it is added to the new set which frames the rules for selecting best optimized path in case of fault occurrence.

Illustrated with Example:

If the selected optimal path produced by fuzzy inference engine rule is termed as R_1 degree of evidence. If the rule generated for the optimal path route selected is R_1 then the favorable degree of evidence R_1 is represented by μ_{R1} and the unfavorable degree of evidence is represented by λ_{R1}

$\mu = .85$ and$\lambda = 0.4$

According to the Paraconsistency against the rule R1 it is calculated as follows

$$D_c(R_1)=\mu_{R1}- \lambda_{R1}$$

$$D_c= 0.85 – 0.4 =0.45$$

$$D_{ct}(R_1)=\mu_{R1}+ \lambda_{R1} - 1$$

$$D_{ct}(R_1)= 0.85 + 0.4 -1 = 0.25$$

The degree of certainty on the rule $R_1D_c(R_1)$ is 0.45 and the degree of condradiction on the rule R_1 $D_{ct}(R_1)$ is 0.25

These paraconsistency is represented as

$$PL\ (D_c,D_{ct})= PL_{R1}(0.45,0.25)$$

Example: To determine degree of evidence

D_c= 0.4 &D_{ct} = 0.2

$$F(\mu, \lambda) = \left(\frac{1}{2}D_c + \frac{1}{2}D_{ct} + \frac{1}{2}, \frac{-1}{2}D_c + \frac{1}{2}D_{ct} + \frac{1}{2}\right)$$

F (μ, λ) = (8, 0.4)

μ = .82 λ = .18

D_c= μ-λ =.82 - .18 = 0.64

D_{ct}= μ + λ -1 =.82 + .18 -1 = 0

μ1 = 0.9 &μ2 = 0.4

μ2 = λ = 1- μ2 = 1- 0.4 =0.6.

(μ,λ) = (0.9, 0.6)

D_c= μ - λ = 0.3

D_{ct} = μ + λ -1 = 0.5

Example: Fault occurrence due to link failure has severe obesity

Expert 1: The possibility of link failure for the selected route ranges from 25 – 40

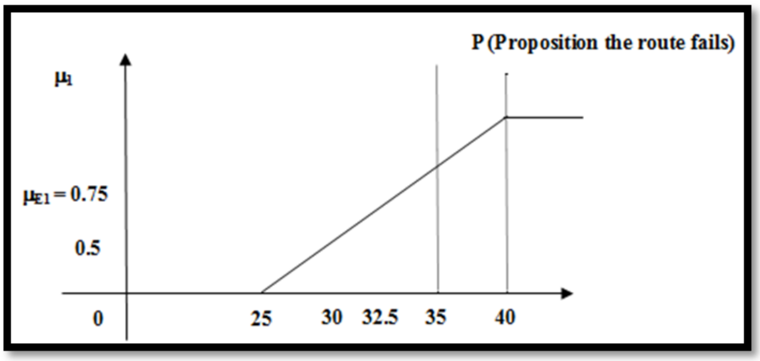

Figure 5: Expert1: The possibility of link failure for the selected route ranges from 25 – 40

$\mu_{(x)} = \frac{x-25}{40-25}$, if x ϵ [25, 40]

1 if x > 40

0 if x < 25

Expert 2 : The member ship value of fault discovery is 85.3

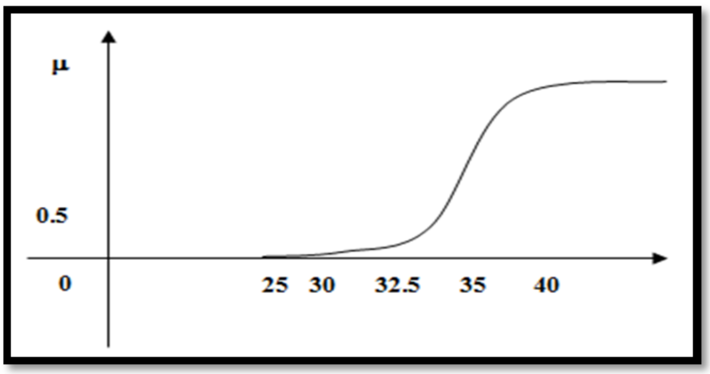

Figure 6: Expert2 :The member ship value of fault discovery is 85.3

$$\mu_{r} = \begin{cases} 0 & x < 20 \\ 2\left|\frac{x-20}{40-20}\right|^2 & 20 \le x \le 30 \\ 1-2\left|\frac{x-20}{40-20}\right| & 30 \le x \le 40 \\ 1 \quad x > 40 \end{cases}$$

Degree of evidence & E1

$$\mu_{(x)}\ E_1 = \frac{35.3-25}{40-25} = 0.686666$$

$$\mu_{(x)}\ E2 = 1\text{-}2\left(\frac{35.3-40}{40-20}\right)^2 = 0.88955$$

$$\lambda_{(x)}\ E2 = 1\text{-}\ 0.88955 = 0.11\quad 045$$

$$(\mu, \lambda) = (0.68666, 0.11045)$$

IV.Experimental Result

In order to determine how the performance of the proposed algorithm compares with other competing algorithms, an *ad hoc* network with mobile nodes was simulated, and dynamically changing topologies, and ran our proposed algorithm along with the other two algorithms AOMDV and BRSR in the simulated environment

Table 2: Simulation Parameters

Simulator Network	Simulator version	ns2.34
Antenna	Type of Antenna	Antenna/ OmniAntenna
ifqType	Type of Queue	Queue/DropTail/ priQueue
Channel type	Type of wireless channel	Channel/WirelessChannel
Radio-propagation model	Wireless propagation model	Propagation/ TwoRayGround
Network interface type	Type of physical interfaces	Phy/WirelessPhy
MAC type	The MAC layer	Mac/802.11
Link layer type	The link layer Link Layer (LL)	LL
ifqLen	Length of the Queue	50
Area (mxm)	Size of simulation field	800 x 800
Routing protocol	The routing protocol	AOMDV, M-AOMDV
Energy model	WSN energy model	Energy Model
Transport protocol	Open Systems Interconnection (OSI)	Transport-layer protocol Transmission Control Protocol (TCP)

Two metrics were used for evaluating the performance of the algorithms invoked in the experiments:

***a. Percentage of packets delivered*:** This represents the rate of successful delivery of packets to the destination. This is calculated as follows. At each second, the packet delivery probability of all the paths in use is calculated. Then, for each packet sent at that time unit, a random number between 0 and 1 is generated. If the number is lower than the packet delivery probability, the packet is considered as delivered. After all the iterations, the percentage of delivered packets is calculated as follows:

$$\text{Percentage delivered packets} = \frac{Total.Numberofdeliveredpackets}{TotalNumberofsentpackets}$$

***b. Overhead*:** This represents the overall number of packets sent. The overhead is calculated as the product of the total length of all paths in use, and the number of packets sent per second.

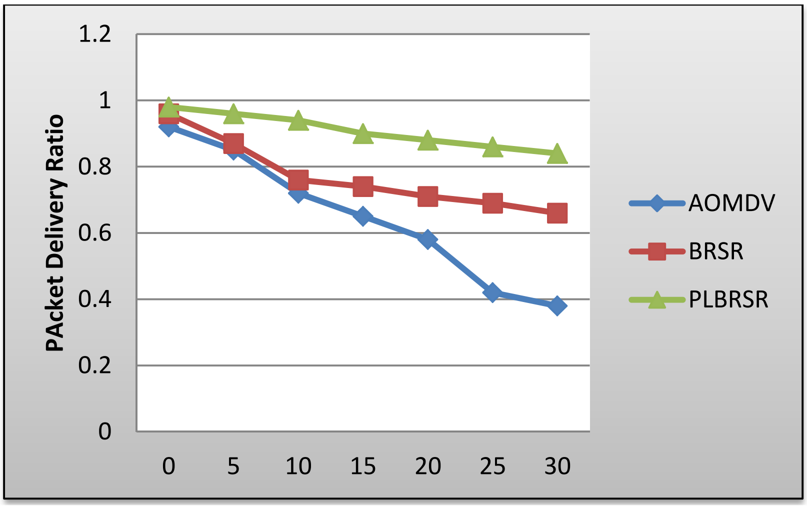

Figure 7: Packet Delivery Ratio vs Percentage of Misbehaving Nodes

In Figure 7 plots the packet delivery ratio of PLBRSR in comparison with AOMDV and BRSR under varied number of misbehaving nodes. The following observations from this figure packet delivery ratio of PLBRSR is consistently higher than other two algorithms in the presence of varied number of misbehaving nodes. .

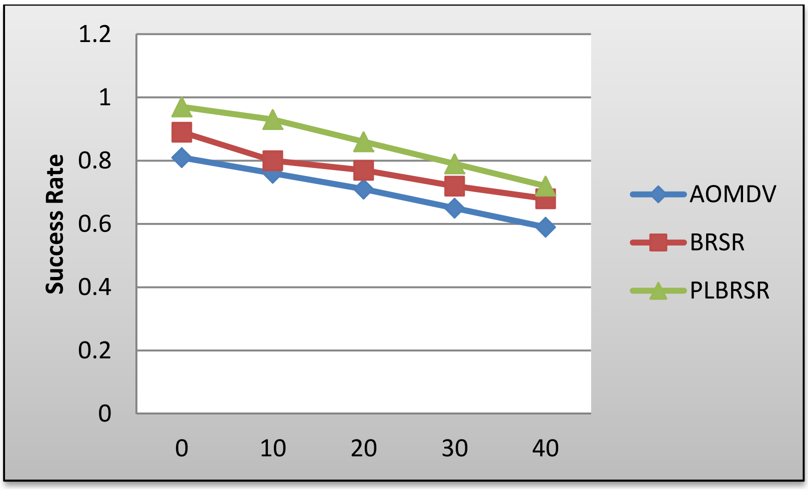

Figure 8: Percentage of Misbehaving nodes vs Success Rate

In Figure 8,the feasible path usage percentage of PLBRSR, BRSR and DSR are plotted respectively. It shows that PLBRSR has a much higher success rate in using the feasible path than other two algorithms due to handling of contraction in rule generation. Using a feasible path to deliver packets obviously increases the packet delivery ratio of PLBRSR.

The results of the following three sets of experiments are presented below:

a. Variation in pause time

b. Variation in sparsity

c. Variation in faultiness of nodes

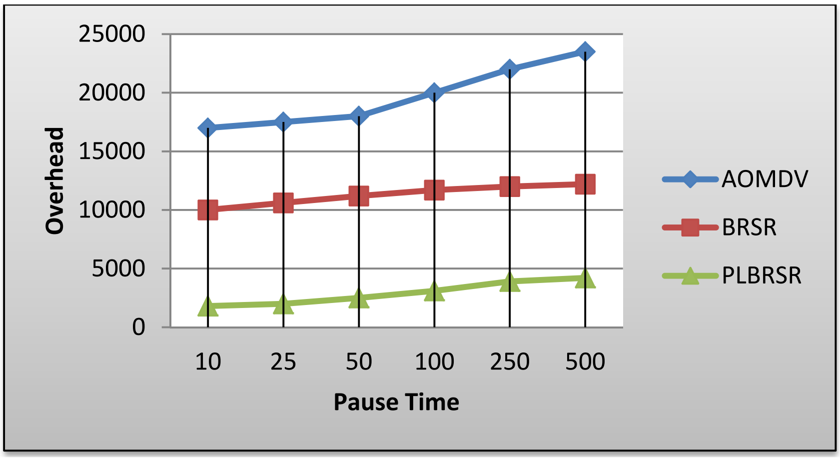

Figure 9:Variation in pause time

In Figure 9 Pause time is a simulation parameter which indicates how much an algorithm is capable of accommodating the mobility of the nodes. The accommodation of mobility modes is higher in the proposed routing algorithm PLBRSR compared to BRSR and AOMDV

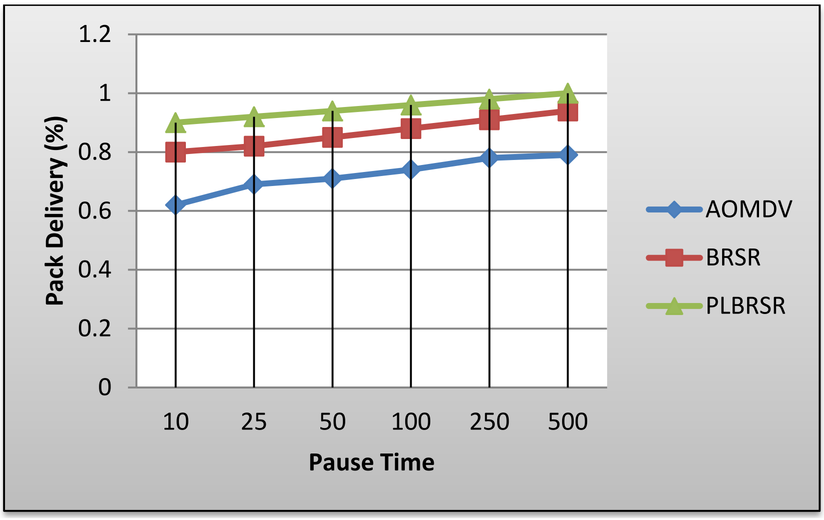

Figure 10: Pause time Vs Packet Delivery Ration

In Figure 10 presents the packet delivery ratio of both the protocols. Since the packet drop is less and the throughput is more, PLBRSR achieves good delivery ratio, compared to AOMDV and BRSR

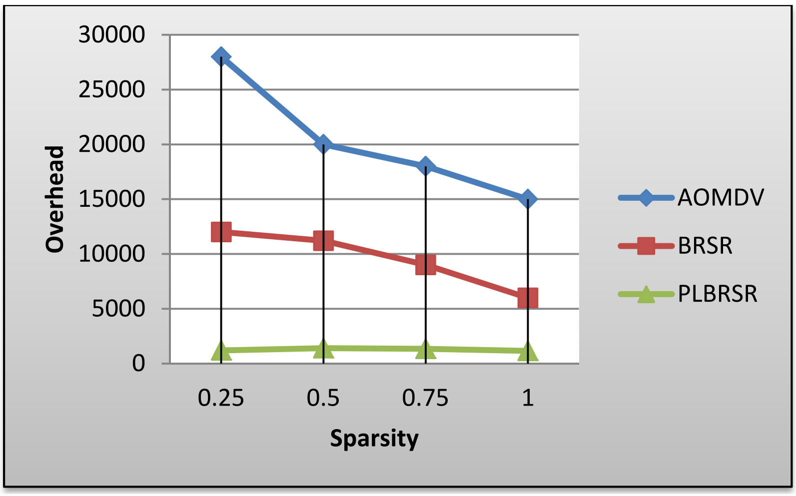

Figure 11: Sparsity Vs Overhead

In Figure 11 the nodes are mobile, how often they connect depends on how close they can get to one another, and this is thus directly related to the Sparsity. The connectivity with neighboring nodes with the knowledge of inference of fault tolerance using paraconsistent logic the PLBRSR produces better connectivity.

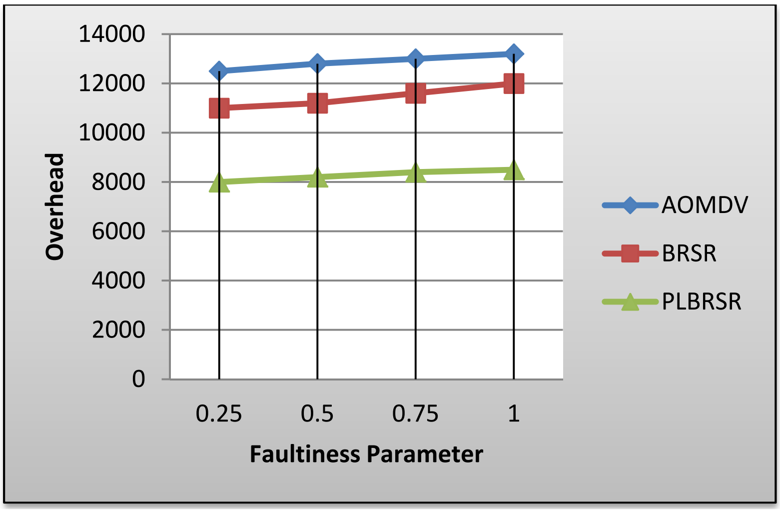

Figure 12: Faultiness Parameter Vs Overhead

In Figure 12 Faultiness is an internal simulation parameter that indicates how many nodes will be faulty in a given environment. It influences the faultiness behavior of the nodes, given their distance from the centre of the region of operation of the nodes. The path selection of PLBRSR based on fault tolerance produces stabilized result by considering faultiness of the nodes in the selected path thus avoiding link failure.

V. CONCLUSION

In this paper we have proposed enhancement of Multipath Routing Protocol for Fault tolerance in MANET, a routing protocol which provides multipath discovery, efficient utilization of bandwidth and controlled traffic load route recovery at the time of failure. It utilizes the paraconsistent logic which works fine in the situation of contraction rule generation based on the energy consumption, queue size, Bandwidth and link stability as the parameters of measuring the fault occurrence and the selection of optimal path which holds the quality of fault tolerance in any adversial environment. The result shows that the proposed work Paraconsistent Logic based BRSR produces favorable output compared to the existing BRSR and AOMDV due to the nature of handling indeterminacy in selection of optimal shortest path.

Provide a statement that what is expected, as stated in the "Introduction" chapter can ultimately result in "Results and Discussion" chapter, so there is compatibility. Moreover, it can also be added the prospect of the development of research results and application prospects of further studies into the next (based on result and discussion).

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