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A Fuzzy Based Adaptive Gateway Discovery Algorithm for Hybrid Multi-hop Wireless Networks

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Abstract

The portable devices such as mobile phones, laptops or personal digital assistants (PDAs) are used by mobile ad hoc networks (MANETs) for communication establishment in a spontaneous manner. For fulfilling the coverage requirements of future 4G we need integration of mobile ad hoc network with Internet to enhance the pervasiveness and flexibility of networks. It is necessary for mobile nodes to identify and choose an optimal gateway among multiple gateways for Internet access. Therefore, a mechanism for gateway discovery is needed. The adaptive gateway discovery can be configured by dynamically adjusting its TTL value (proactive area) on the basis of several parameters like number of active source nodes, traffic load at the gateway and link changes. Existing schemes involve inaccurate estimation of optimal proactive area, hence they suffer from large routing overhead which ultimately affects the network performance and throughput. This paper aims to develop a novel and efficient adaptive gateway discovery algorithm focusing on optimal TTL value by utilizing the potential and capability of Fuzzy logic, which makes a significant impact on routing overhead during gateway discovery. The proposed scheme also incorporates efficient handover in the situation of multiple gateways so that single gateway will not become a bottleneck. The proposed approach is evaluated using computer simulation and also analytically validated. Results show our approach outperforming existing ones.

***Key Words*:** MANET, Fuzzy Logic, Adaptive Gateway Discovery, TTL (Time-to-live), Handover

1. Introduction

Mobile ad hoc network (MANET) is a wireless network which is created dynamically without the use of any existing network infrastructure or centralized administration. The integration of MANET and fixed IP network such as Internet is desired to provide network coverage extension and also to enhance the domain of adhoc network applications. The architecture of such network differs from Internet as it makes assumptions of various sorts on the dynamic topology structure, and communication patterns in lieu of such differences, therefore integrating different networks to form a heterogeneous network is a challenging issue. Internet gateways act as an interface between a MANET and the Internet for achieving Internet connectivity. Hence, modification of MANET routing protocol is needed for achieving MANET-Internet integration. The challenge in the integration of MANETs with Internet lies from the need to inform mobile nodes about all possible available gateways in a highly dynamically topological scenario while ensuring minimum consumption of network resources [1]. Hence, efficient Internet gateway discovery for mobile ad hoc networks is one of the distinguished features required for hybrid

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mobile ad hoc networks in future wireless and mobile networks. As MANET exhibits a multi-hop nature, there may be proximate gateways for a mobile node at specific moment of time. If the gateway advertisement is received by a mobile node from different Internet gateways, it has to decide which gateway is to be selected for providing Internet connectivity [2].

The limitation to overcome is that there is not any mathematical relationship among number of active source nodes, traffic load at the gateway and link changes to estimate optimal TTL value for propagating gateway advertisement (GWADV) advertisements [3]. The proposed algorithm adapts optimal proactive area dynamically using fuzzy logic. Fuzzy systems can capture the generic behavior of the MANET as per the parameters setting. Making effective fuzzy rule base on the basis of parameters discussed can improve network performance such as packet delivery ratio (PDR), routing overhead and end-to-end delay.

1.1 Contributions

The specific contribution of the paper is to design a novel adaptive gateway discovery algorithm which focuses on determining an optimal proactive area on the basis of TTL value derived using the potential and capability of fuzzy logic. This technique makes a significant reduction in routing overhead. Our approach also incorporates efficient handover in the situation of multiple gateways so that single gateway will not become a bottleneck and suffered from congestion by the use of additional augmented field namely *effective_queue_load* and timestamp factor.

1.2 Organization of the Paper

The remaining paper is organized as follows: The related work about various gateway discovery mechanisms and its implementation on fuzzy logic are discussed in section 2. Our proposed gateway discovery mechanism is presented in section 3. The analytical validation of our proposed approach is discussed in section 4. Our simulation results are remarked in section 5. Finally, in section 6 the paper is concluded with directions of future work.

2. Related Work

Ruiz et al. [4] proposed maximal source coverage (MSC) algorithm in which Internet gateway broadcasts advertisement message having TTL (time to live) field set to minimum hop count needed to reach all sources covered by this gateway for providing Internet connectivity. The proactive area is not dynamically varied as per the current traffic scenario.

The enhancement to Ruiz et al. [4] stated by Ros et al. [5] that intermediate nodes can act as proxy for the Internet gateway. The proxy nodes can reply in unicast to the modified router advertisement message on behalf of Internet gateway which results in reduction of proactive zone, they named it as low overhead and scalable proxied (LOSP) algorithm.

Ghassemian et al. [6] proposed hybrid and adaptive centralized algorithm in which an auto-regressive filter is used to adjust TTL value and advertisement periodicity (T) simultaneously. The traffic load is monitored by Internet gateways so that TTL and T can be set with the help of feedback controller. Feedback controller is used for behaviour optimization in unpredictable environments. The proposed adjustment is done on the basis of traffic rate, changes in link stability, and number of MRS (modified router solicitation) messages received. The MRS message emitted by a mobile node to Internet gateway when it requires a route to communicate with fixed IP node in a reactive manner. However, no specific evaluation and formulation is specified.

A hybrid gateway discovery approach was proposed by Ratanchandani et al. [7] in which AODV and two Mobile IP foreign agents are used for MANET-Internet interconnection. However, foreign agent's advertisements are restricted to limited TTL value. Therefore, only those mobile nodes that are proximate to one of the foreign agents can receive the gateway advertisements. Nodes that are outside this zone have to reactively solicit the advertisements.

Lee et al. [8] proposed a versatile approach in which advertisements are propagated on the condition when there is a change in the topology. However, their proposed approach relies on source routing protocol, which itself has the scalability and applicability limitations.

An adaptive gateway discovery scheme was proposed by Bin et al. [9]. In this scheme, the proactive areas of gateway advertisement messages are dynamically adjusted as per Internet traffic of the mobile nodes and their relative location from Internet gateways to which they are registered. Internet access to MANET nodes is provided by mobile IP.

Kumar et al. [10] analyzed existing load-aware routing protocols in MANET and then based on this analysis; devise a proactive load-aware gateway discovery scheme that considers the interface queue size besides traditional min. hop count metric. Efficient handoff procedure from one Internet gateway to another is provisioned in this approach while ensuring connectivity to a fixed host in a seamless manner. However, it does not consider optimal TTL value calculation before passing its proactive gateway advertisement.

Vanjara et al. [11] proposed complete adaptive gateway discovery protocol in which the decision of TTL of GWADV message is based on the maximum benefit coverage [11]. The frequency of advertisement (T) is determined by regulated mobility degree (RMD). Regulated mobility degree indicates the mobility of nodes in the network. The proposed algorithm is heuristic in nature and an adaptive advertisement is decided whether to perform or not according to situation. The limitation of this approach is threshold estimation as its optimal value which is itself network condition dependent.

Zaman et al. [12] stated an adaptive gateway discovery scheme which considers periodicity and range of a Internet gateway advertisement message and also focus on load balancing during packet routing. The proactive zone is dynamically adjusted according to average hop metric. A modified form of the fuzzy mechanism taking into account three metrics namely number of received gateway solicitation (GWSOL) messages, Link changes (LC) and TTL changes that are used to dynamically adjust the periodicity of the GWADV messages. Load balancing is achieved by calculating route queue length, gateway queue occupancy and path load. The drawback of this solution is greater end to end delay due to large computational overhead occurred during gateway discovery process.

Zaman et al. [13] proposed an adaptive gateway discovery protocol viz. MFC (Mamdani fuzzy control) based on mamdani architecture for fuzzy control. In this approach it dynamically adjusts the periodicity of gateway advertisement based on three parameters namely average number of hops, aggregate interface queue length (AIQL) and number of nodes registered with the Internet gateway. In this integrated MANET-Internet architecture WLB-AODV [14] approach has been used for gateway load balancing. The two issues of gateway discovery and load balancing have been taken care off in this integration strategy. In this, author uses handover from one gateway to another according to path load.

A new Adaptive gateway discovery scheme viz. FGD (fuzzy based gateway discovery) was proposed by Yuste et al. [15] in which the gateway advertisement (T) frequency is optimized using fuzzy logic system and TTL value is varied according to traffic load. However this scheme does not focus on efficient handover scheme and determination of optimized proactive area which is also primarily important to improve network performance.

Yuste et al. [16] proposed an inclusion of fuzzy logic system which is installed in the adhoc mobile nodes in a distributed fashion to identify routes which are stable in order to enhance MANET-Internet integration. The optimization is based on the routing messages which are selectively forwarded and is governed by fuzzy system. The type II fuzzy logic decision system has the capability to handle uncertainty of node mobility. Limitation of this approach lies in the estimation of specified threshold values periodically due to precise rules used in fuzzy system. This prevents forwarding of gateway advertisement messages adaptively. Therefore, the protocol behaves like reactive protocol hence degrading the performance due to increase in the end-to-end delay.

3. Proposed Gateway Discovery Mechanism

Our proposed approach is incorporated with the help of mamdani based fuzzy system on the basis of several parameters to identify optimal TTL value. The parameters used as input are as follows:

1. Number of active source nodes (ASN): Active source nodes are nodes which are producing data traffic from mobile adhoc region to fixed IP node. The membership function for this input (snapshot) is shown in Figure 1.
2. Traffic load at the gateway: The traffic load is the number of control and data packets arrived at the gateway. (Values ranging from $\lambda_i K_i$ where i is the number of active nodes). The membership function for this input (snapshot) is shown in Figure 2.
3. Link changes: This parameter indicates the nodes mobility around the Internet gateway. It is computed as the ratio of number of link changes as detected by the gateway to the number of active sources. Membership function for this input (snapshot) is shown in Figure 3.

The fuzzy rule base for determining optimal proactive area is described in Table 1. These three parameters are passed through fuzzification process and inference engine integrated with fuzzy rule base and subsequently defuzzify to get the optimal value. The optimal value determines the proactive area equivalent to number of hops the GWADV advertisement will propagate.

Most of the existing gateway selection approaches use shortest path algorithm to choose gateway using minimum hop count to find the route towards gateway. The advantage of using such approach is less consumption of network resources. However, if the nearest gateway is selected by all mobile nodes for Internet connectivity, then this Internet gateway becomes a bottleneck which leads to high processing latency and overutilization of a particular gateway.

In this paper, an additional metric namely *effective_load_queue* and timestamp factor is introduced in the

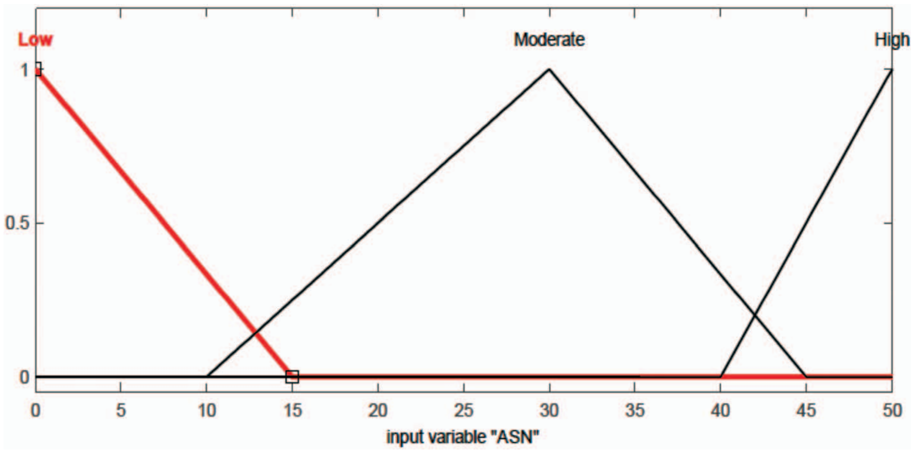

Figure 1. Membership function for active source nodes.

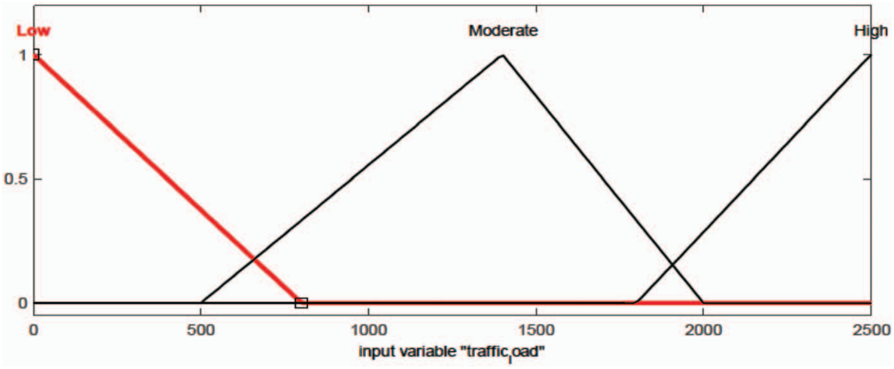

Figure 2. Membership function for traffic load.

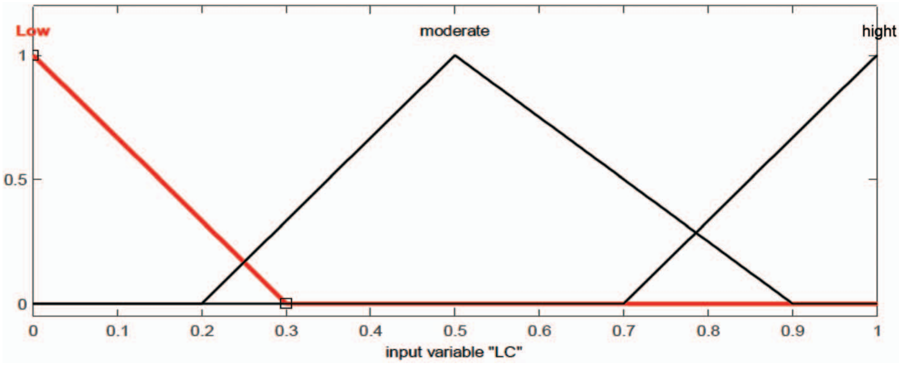

Figure 3. Membership function for link changes.

Table 1. Fuzzy Rule base for determining optimal proactive area

Number of active source nodes (ASN)	Traffic load at the gateway (TL)	Link changes (LC)	TTL_value
High	Low	Low	Low
High	Low	Moderate	Moderate
High	Low	High	High
High	Moderate	Moderate	High
High	Moderate	High	High
High	High	Low	High
High	High	Moderate	High
High	High	High	High
Low	Low	Low	Low
Low	Low	Moderate	Low
Low	Low	High	Low
Low	Moderate	Low	Low
Low	Moderate	Moderate	Low
Low	Moderate	High	Moderate
Low	High	Low	Low
Low	High	Moderate	Moderate
Low	High	High	High
Moderate	Low	Low	Moderate
Moderate	Low	Moderate	Moderate
Moderate	Low	High	Moderate
Moderate	Moderate	Low	Moderate
Moderate	Moderate	Moderate	Moderate
Moderate	Moderate	High	Moderate
Moderate	High	Low	High
Moderate	High	Moderate	High
Moderate	High	High	High

modified gateway advertisement format which is used for the selection of a particular gateway and efficient handover scheme is also incorporated in the situation of multiple gateways along with the implementation of a determination of a proactive area. Thus, our scheme provides a unique combination of adaptive gateway discovery and efficient handover scheme. Gateways periodically broadcast gateway advertisement having additional field consist of *effective_load_queue* and timestamp factor. *effective_load_queue* is estimated by taking in to account the cumulative effect of interface queue load along the gateway route. For this scenario implementation, the field *total_path_load* is also maintained at each mobile node routing table to record the total load along the route towards gateway in the routing table for which the optimal path is selected. The source node always select gateways with less value of effective load queue and high response time (low value of time stamp) so that the traffic is distributed evenly among other gateways resulting in lower chances of collision and packet loss due to high congestion. The gateway having low value of timestamp in modified gateway advertisement format indicates that the advertisement has arrived through the path having less congestion and delay. The modified gateway advertisement message format is used in our approach is shown in Figure 4.

3.1 Network Architecture

3.1.1 Scenario of the Proposed Approach

The architectural scenario of the proposed approach is shown in Figure 5. Here G1 and G2 are gateways which provide connectivity to the Internet, A to M are mobile nodes connected by wireless links, the optimal proactive area is determined through Mamdani based fuzzy inference system. Suppose G1 broadcasts a gateway adver-

Type	Reserved	Prefix Size	Hop Count
Broadcast ID			
Destination IP Address			
Destination Sequence Number			
Source IP Address			
Lifetime			
effective_load_queue			
timestamp			

Figure 4. Modified gateway advertisement format.

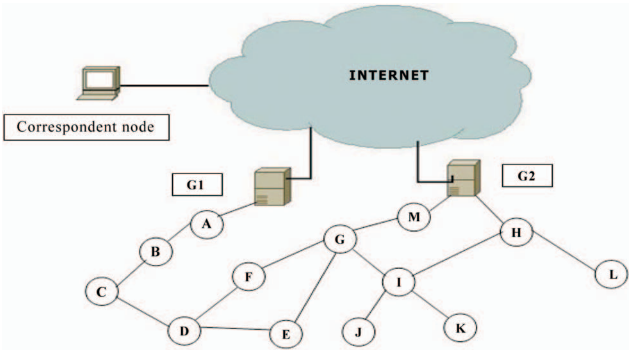

Figure 5. Architecture of the proposed scenario.

tisement (GWADV) during proactive approach with *effective_load_queue* and timestamp, as the advertisement propagates through various current value of effective_load_queue is updated and is compared with *total_path_load* and timestamp, if the current value of *effective_load_queue* is less than *total_path_load* and lesser timestamp then that gateway is chosen as it reflects the optimal path through which the advertisement come. Algorithm 1 describes gateway discovery is given below:

Algorithm 1. Gateway discovery

Input: A network graph G = {V, E}, a source node S, a set of Gateways G and a destination node D

Output: Optimal TTL value, Optimal selected gateway on the basis of low timestamp value

Step 1: Computation of proactive area using Fuzzy logic on the basis of number of active sources.

Step 2: Gateway advertisement (GWADV) is produced with the updated value of *effective_load_queue* and time stamp factor.

Step 3: For each unique Internet gateway advertisement at a particular node

effective_load_queue = current value of *effective_load_queue* + avg_q_load at a particular node

Hop_count = Hop_count + 1;

Step 4: At a particular node if (*effective_load_queue* <= *total_path_load*) and (timestamp (G1) < timestamp (G2))

// total_path_load is maintained at every node's routing table

Select gateway (G1);

else

Select gateway (G2);

Step 5: *total_path_load* = *effective_load_queue*;

Hopcount = *Hop_ count*; //current value of hop count is updated at routing table

Update next hop address;

Step 6: *if* gateway advertisement is received from a different gateway

Hand off to another Internet gateway subject to the fulfillment of condition as stated in step 4,

else if gateway advertisement is received from a different gateway having same value of effective_load_queue and timestamp

Hand off to another Internet gateway if current serving gateway hop_count > received gateway advertisement hop_count

else

Continue with existing gateway

Step 7: Select new optimal Gateway as default Gateway if hand off is occurred.

Step 8: Update *total_path_load*, default_path_seqno, Hopcount etc. in the routing table.

The fuzzy based decision system is presented in Figure 6. in which three variables namely number of active source nodes, traffic load and link changes are passed through fuzzification process and then mapping input to output space is governed by inference system using fuzzy rule base and finally defuzzify to get the ttl_value quantifying the optimal proactive area.

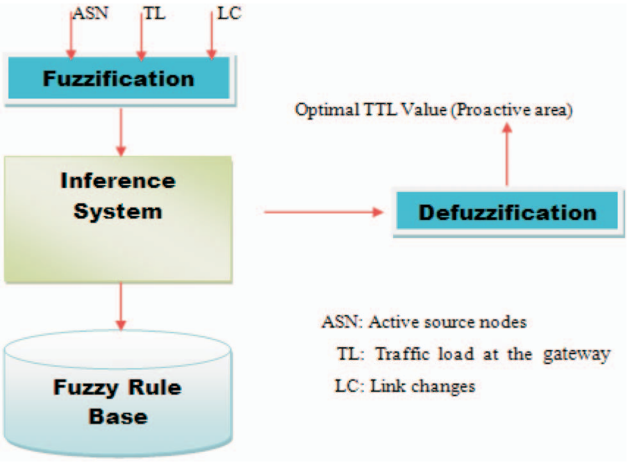

Figure 6. Fuzzy based decision on Optimal TTL value.

The fuzzy implementation is performed in MATLAB. The fuzzy based rule viewer given in Figure 7 reflects various combinations and possibilities of input variables that can occur and combining these conditions various rules are framed, finally a desired output is achieved using this fuzzy system.

The surface viewer results obtained in Figure 8 embarks the output value variation with their input variables.

4. Analytical Model

For analytical evaluation [4] of our proposed approach, a rectangular lattice representing mobile ad hoc

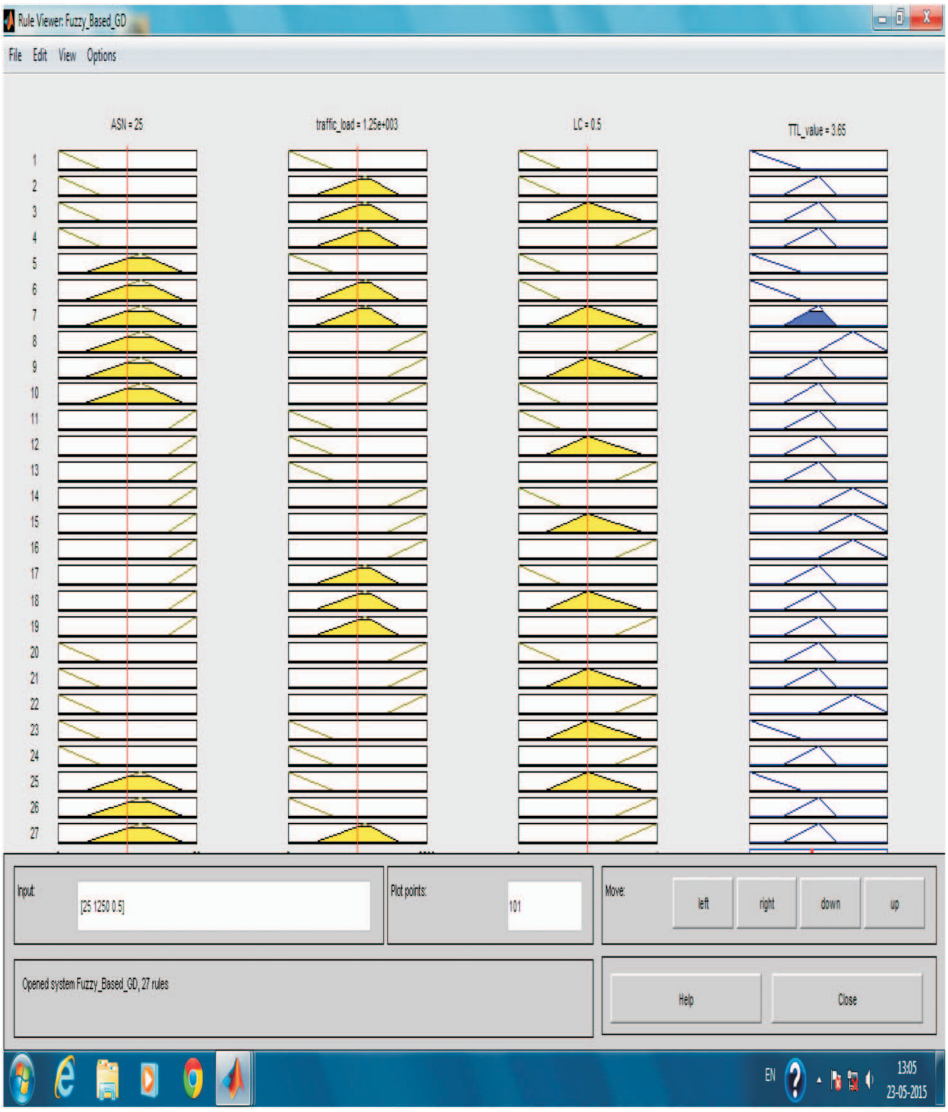

Figure 7. Fuzzy based rule viewer.

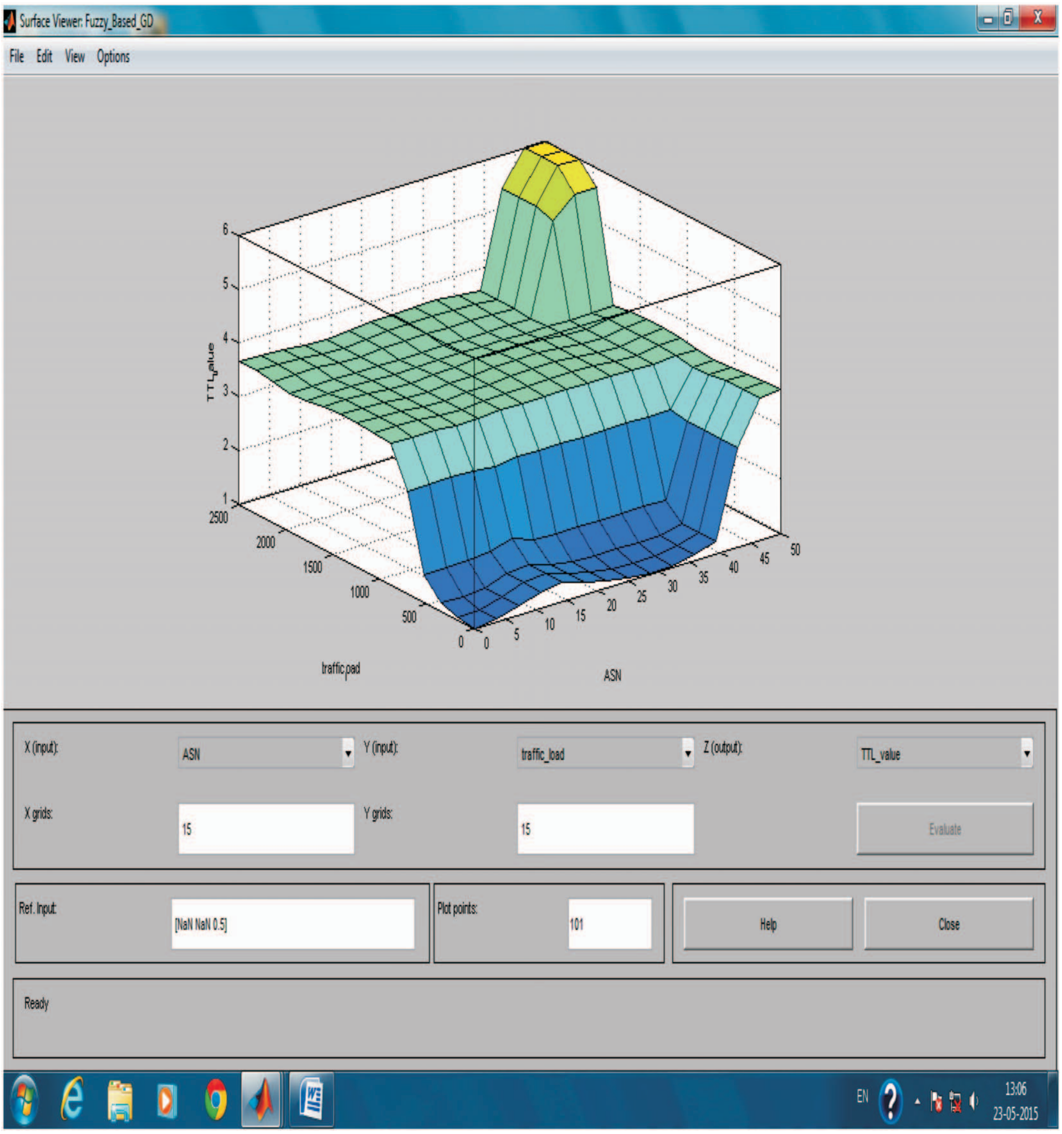

Figure 8. Surface viewer obtained from fuzzy inference system.

nodes uniformly distributed over it as shown in Figure 9 covering specified area. Each lattice vertex represents the possible node location. Assuming a node n is placed over the lattice there are 4k nodes from n at a distance of k hops. Ad hoc nodes are placed over the Kth concentric circle centered over the node n. Therefore at a distance of k hops, the total number of nodes $N_r(k)$ is given by eq. (1).

$$N_r(k) = 1 + \sum_{j=1}^{k} 4j = 1 + 2k(k+1),\ k = (\sqrt{2N-1}-1)/2 \quad (1)$$

where N represents the total number of nodes.

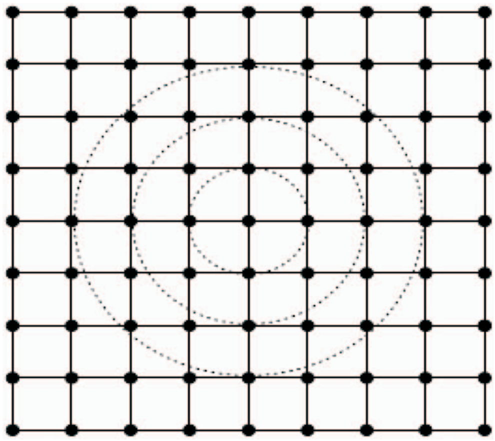

Figure 9. Square lattice used.

Whenever a source node searches a route towards a fixed IP node it does not get any response within the mobile ad hoc network. Therefore, for each source S, number of messages needed to realize that a destination is a fixed IP node is estimated as per eq. (2) given below:

$$\Omega_{Fixed\ node} = \sum_{j \in \{1,3,5,7,30\}} N_r(j) \tag{2}$$

where $\Omega_{Fixed\ node}$ refers to routing overhead associated with fixed node and j is the j^{th} concentric ring in the rectangular lattice.

Let 'S' represents the number of active sources in a heterogeneous network willing to communicate with fixed nodes, λ_{adv} is the rate of gateway advertisement messages disseminated by the Gateways and 't' is time interval being considered. The overhead occurs due to gateway advertisement message being delivered to ad hoc network is N + 1 message as GWADV (gateway advertisement) message forwarding procedure is carried out by each of the N nodes and the gateway itself. Besides fixed node overhead, we also have to consider that initially all the source nodes in the network need to realize that destination consist of fixed node, then total overhead of proactive approach Ω_p is quantified in terms of number of messages is given by eq. (3).

$$\Omega_p = S \cdot \Omega_{Fixed\ node} + \lambda_{adv} \cdot t \cdot (N+1) \cdot N_{GW} \tag{3}$$

where N_{GW} consist of number of gateways in a hybrid network.

The metric effective_load_queue and timestamp factor is used for route selection towards gateway for communication with hosts in the Internet. Under this scenario we can assume that there are $N_{adhoc} = N - N_{GW}$ potential nodes which are used by Internet gateway for their default routes. Whenever a source performs reactive gateway discovery, RREQ_I message is flooded throughout the network and in response, RREP_I reply is unicasted by every gateway to the source. We have assumed Internet gateways are located in the corners of the lattice therefore the mean path length is $\sqrt{N} - 1$. The overhead of reactive discovery $\Omega_{reactive}$ of the gateways associated with single source can be calculated as given in eq. (4).

$$\Omega_{reactive} = N_{adhoc} + N_{GW} + N_{GW} \cdot (\sqrt{N} - 1) \tag{4}$$

where N_{GW} are total number of gateway nodes and N is the total number of nodes assumed in the model.

The hybrid Internet gateway discovery overhead is the composite overhead of reactive and proactive approaches, the sources that are located outside the proactive area covered by gateway advertisement messages, the overhead is similar to reactive approach. As we have made a assumption that Internet gateways are positioned in the corners of the lattice. Gateways do not send GWADV at TTLs longer than $\sqrt{N} - 1$, as already other gateways will cover beyond that TTL. Therefore the effective TTL value will be in the range expressed as effective ttl_value $\in [0, \sqrt{N} - 1]$. Therefore the expression for overhead is given by the expression is reflected in eq. (5).

$$\begin{aligned} \Omega_{hybrid} = S \cdot \Omega_{Fixed\ node} + \lambda_{adv} \cdot t \cdot (N_{hyb} + 1) \cdot N_{GW} \\ + \Omega_{reactive} \cdot \lambda_{dur} \cdot t \cdot S \cdot (1 - P_c) \end{aligned} \tag{5}$$

For estimating end-to-end delay we have to take into account exponential back off mechanism which is modeled using evaluation of collision probability of each link involved from source to destination.

Assume that a wireless link suffers from collision with a probability p, therefore the transmission is successful at probability (1 − p) with first attempt, after C number of unsuccessful attempts depending on the frame size, it is dropped. Denoting X as the number of attempts for successful transmission [17] of a given frame

$$P(X = k) = \begin{cases} p^k \cdot (1-p) & \text{if } k \le C \\ p^k & \text{if } k = C+1 \\ 0 & \text{if } k \ge C+1 \end{cases} \tag{6}$$

The 'n' number of expected retransmission for a given frame is expressed as given in following eq. (7).

$$n = \sum_{k=1}^{C} k \cdot p^k (1-p) + (C+1) \cdot p^{C+1} \tag{7}$$

where k ranges from 1 to C reflecting unsuccessful attempts.

Now there is a requirement to calculate back off time that affects the delay transmission, assuming that there is no collision then the back off time is determined with its average value

$$\frac{CW_{\min}-1}{2} \tag{8}$$

where CW is congestion window.

When collision occurs, the exponential back off mechanism increases beyond its average value. The expected number of back off slots decremented until the transmission attempts end for a single frame is:

$$backoff' = \sum_{k=1}^{+\infty} P(X=k) \cdot \frac{\min(CW_{\max};\ 2^{k-1} \cdot CW_{\min}) - 1}{2} \tag{9}$$

for simplifying the above expression $CW_{\max} = 2^c \cdot CW_{\min}$ with $c \leq C$.

$$backoff' = \sum_{k=1}^{c} P(X=k) \cdot \frac{2^{k-1} \cdot CW_{\min} - 1}{2} + \sum_{k=c+1}^{C} P(X=k) \cdot \frac{CW_{\max}-1}{2} \tag{10}$$

$$backoff' = \frac{1-p}{2} \cdot \left(\frac{1-(2\cdot p)^c}{1-2\cdot p} \cdot CW_{\min} + \frac{p^c - p^C}{1-p} \right) \tag{11}$$

Therefore, end to end delay which is computed using the formula

$$Delay_t = backoff' \cdot T_{slot} + n \cdot T_c + T_m \tag{12}$$

where n is the mean number of retransmission, T_{slot} is the duration of a slot and T_m is the time to successfully transmit a packet of m bytes.

As we are deriving optimal value of ttl which is derived using fuzzy logic we can conclude GWADV will travel between $[0, \sqrt{N} - 1]$ number of hops and one default hop route from gateway node to fixed node. Hence average end to end delay is calculated as:

$$EtoE_{delay} = ttl\_valueXDelay_t \tag{13}$$

The results obtained through simulation shows a deviation with the analytical evaluation as reflected in Tables 2 and 3 because of difference in mobility, simulation area and MAC on a simulation process. The normalized routing overhead is obtained by ratio of routing overhead obtained in this context and total number of messages sent by the source.

5. Performance Evaluation

The use of simulation tool becomes necessary for analyzing different scenarios, thus our proposed approach is implemented using NS-2 (ns-2.34 version). For simulation evaluation we have considered parameters as given in Table 4. The network scenario consist (s) of fixed number of nodes that is 50 in our case and varying num-

Table 3. Analytical validation of End-to-End delay

End-to-End delay in Milliseconds		
Number of ASN	Fuzzy based Adaptive	
	Simulation	Analytical
15	42	47.5
25	118	119.3
35	198	196.6

Table 2. Analytical validation of normalized routing overhead

Number of ASN	Normalized routing overhead					
	Reactive		Proactive		Fuzzy based Adaptive	
	Simulation	Analytical	Simulation	Analytical	Simulation	Analytical
15	2.65	2.66	2.05	2.20	1.65	1.589
25	3.25	3.26	2.51	2.53	1.75	1.785
35	3.78	3.79	2.21	2.22	2.0	2.135

Table 4. Simulation parameters

Parameters	Values
Number of mobile nodes	50
Number of sources	15, 20, 25, 30, 35, 40
Number of gateways	2
Topology size	1200 × 800 m
Wireless transmission range	250 m
Traffic type	CBR
Packet size	512 bytes
Packet sending rate	5 packets/second
Mobility model	Random waypoint
Interface queue limit (wireless & wired node)	50 packets
Link level layer	IEEE 802.11 DCF
Interval between successive GWADV advertisement	5 seconds
Speed of mobile node	10 m/s

ber of active source nodes. The network topology has a terrain size area of 1200 × 800 m. The proposed scheme is compared with other related state of the art schemes MFC [13] and FGD [15]. Each source generates data packets of size 512 bytes at the rate of 5 packets per second (20 Kb/s). For Internet-MANET integration framework, AODV+ routing protocol [18] was used. We show 95% confidence intervals in each graph but in some cases it is less visible.

5.1 Performance Metrics

- Packet delivery ratio (pdr): It is computed as the ratio of the number of data packet successfully delivered to the number of data packets generated by the sources.

$$pdr = \frac{total\ number\ of\ received\ packets}{total\ number\ of\ sent\ packets\ by\ the\ source}$$

- End to end delay: This metric denotes the overall time for a packet to travel from source to destination.
- Normalized routing overhead (nro): The ratio of the number of control packets to the total number of received data packets provide the value of normalized routing overhead. Also, a retransmitted control packet is considered as a new control packet.

$$nro = \frac{total\ number\ of\ routing\ packets\ sent}{total\ number\ of\ data\ packets\ received}$$

5.2 Simulation Results

The performance evaluation is done on two scenarios one having varying number of active source nodes ranging from 15 to 40. Another one in which pause time is varied to determine the performance of the protocol under different mobility conditions considering moderate value of active source nodes taken as 20.

(a) Effect of varying source nodes: The packet delivery ratio is evaluated with respect to varying active source nodes as shown in Figure 10. Our proposed approach shows best performance outperforming others as the numbers of active sources are rising. The packet deliver ratio falls when there is more number of nodes, the greater will be the route updation, more packet lost etc. Comparable with other state-of-the-art related schemes, the optimized performance is due to efficient handover scheme which does not cause congestion neither at the gateway nor its associated path from source node to gateway. Hence, packet drop will be less.

The end to end delay with respect to varying number of active number of source nodes is shown in Figure 11. The end to end delay is less as compared to other approaches as optimal TTL value consideration causes prior updated route and hence route searching in a reactive manner is very less, consequently end to end delay is less.

The normalized routing overhead with respect to varying number of active number of source nodes is shown in Figure 12. The routing overhead is less as compared to other approaches due to optimal TTL value con-

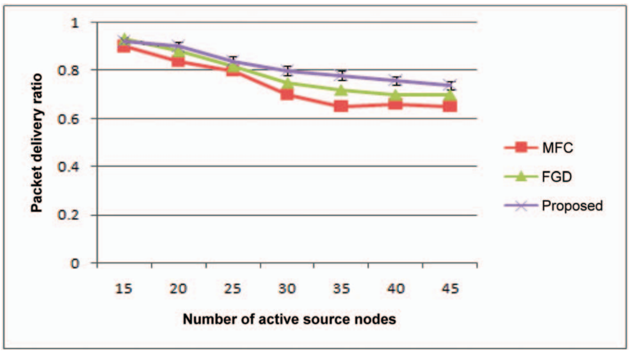

Figure 10. Packet delivery ratio vs number of active source nodes.

sideration and efficient handover scheme, consequently congestion and overhead is less.

(b) Effect of node mobility: The packet delivery ratio is evaluated with respect to varying pause time as shown in Figure 13. Our proposed approach shows better performance than others as mobility decreases. Low pause time implies increase in mobility which makes frequent topology changes and link breaks.

The end to end delay is evaluated with respect to varying pause time as shown in Figure 14. Our proposed approach shows less end to end delay than others as mobility decreases. The end to end delay is less as compared to other approaches as optimal TTL value consideration causes prior updated route, and in low mobility situation frequent topology changes and link breaks will be less, hence end to end delay is less.

The normalized routing overhead is evaluated with respect to different mobility conditions are shown in Figure 15. Our proposed approach shows less routing overhead due to precise optimal value derived from fuzzy system. Also in low mobility situations, frequent topology changes and link breaks will be less, hence routing overhead is less.

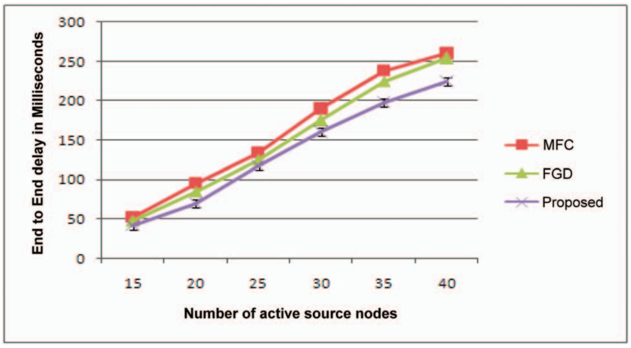

Figure 11. End to End delay vs number of active source nodes.

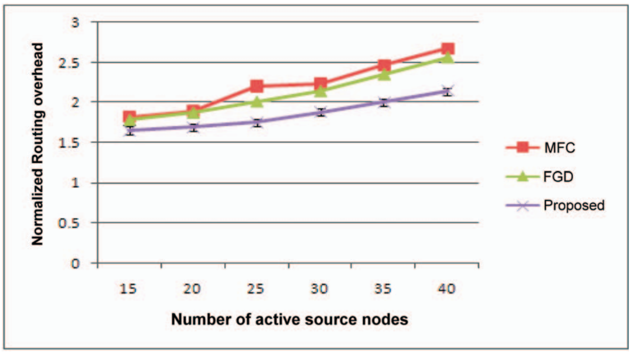

Figure 12. Normalized routing overhead vs number of active source nodes.

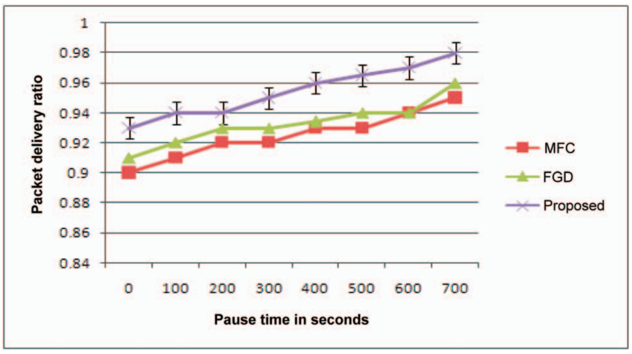

Figure 13. Packet delivery ratio vs pause time.

6. Conclusions and Future Scope

The integration of MANET and Internet requires an efficient gateway discovery mechanism which provides network throughput without suffering network performance. As reactive and hybrid schemes of gateway dis-

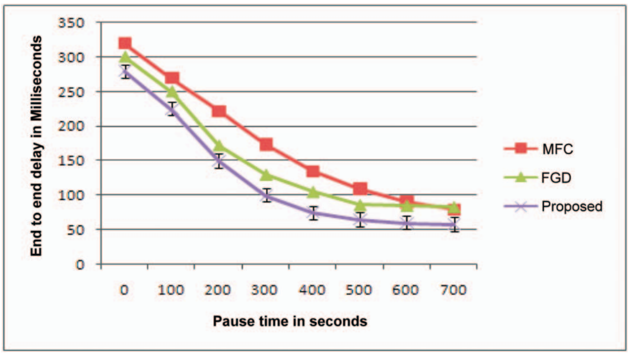

Figure 14. End to end delay vs pause time.

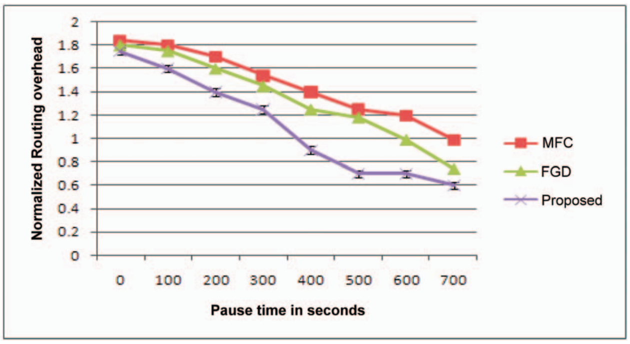

Figure 15. Normalized routing overhead vs pause time.

covery incurs huge overhead which certainly afflict the performance our proposed approach is focused on optimal calculation of proactive area utilizing the potential of fuzzy logic, hence incorporating effective adaptive gateway discovery technique based on parameters discussed in the paper. The proposed approach also incorporates efficient handover scheme in which the selection of gateway can be dynamically changed if the other gateway is reflecting less loaded status or least congested path. The overhead of fuzzy logic may include computation time which is almost negligible as it takes the decision in instantaneous manner based on the latest information available. However the benefit provided by this approach is more significant than its minor overhead. Performance evaluation of our proposed approach shows better performance than existing approaches. The results have also been analytically validated in terms of normalized routing overhead.

As a part of our future work, we integrate dynamic calculation of gateway advertisement periodicity with our proposed scheme to further reduce the overhead.

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