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Ant Pheromone Evaluation Models Based Gateway Selection in MANET

Naveen Kumar Gupta[1], Deepak Gupta[2], Rakesh Kumar[3] and Amit Kumar Gupta[4]

[1]Department of Computer Science and Engineering,
Motilal Nehru National Institute of Technology, Allahabad, India
naveenkumar.gpt@gmail.com

[2]Mathematics Department,
SR Group of Institutions, Jhansi, India
deepakjhansi2007@rediffmail.com

[3]Department of Computer Science and Engineering,
Madan Mohan Malaviya University of Technology, Gorakhpur, India
rkiitr@gmail.com

[4]Image Enterprises, Gurgaon, Haryana India
amitguptaedu053@gmail.com

Abstract: **A mobile ad hoc network (MANET) is an infrastructure less, low cost, small range autonomous network where mobile devices can share the data as well as resources. If any mobile node in MANET wants to communicate with fixed host, it requires discovering an appropriate Internet gateway. A novel adaptive gateway discovery scheme using ant like mobile agent has been proposed in this paper. Ant releases a chemical substance called Pheromone. In this paper, different pheromone evaluation models are used to calculate this pheromone value. On the basis of pheromone value, traffic and route stability has been analyzed. To calculate this pheromone value, different pheromone evaluation models are discussed in this paper. These models provide an adaptive route to a gateway in different conditions. A discovery value is computed and used in selecting an optimal gateway in case of multiple gateways. The analytical study carried out in this paper validate that ant scheme with different model provides a better route discovery than existing ones. The proposed scheme also provides a stable and an optimal route between a mobile node and particular gateway.**
Keywords: Ant-like mobile agent, Pheromone value, pheromone, evaluation model, Discovery value.

I. Introduction

A mobile ad hoc network is a type of ad hoc network which can be established as per requirement in small range. It is autonomous, self configured, infrastructure less in nature where each mobile node can move arbitrary within a particular range. A node in MANET can use the resources of another node. A MANET can be a Wi-Fi connection, or any other medium, such as satellite or cellular connection. This network doesnt require any central administration. Nodes can be mobile devices also. So node can move within the range. An arbitrary node within the range can join network and communicate with other nodes of the network. But there is a limitation with MANET that a node in MANET cannot communicate outside the network or Internet. To communicate with the Internet, it requires an Internet gateway. Internet gateway provides communication between the local network and global network i.e. Internet. So gateway discovery techniques are needed as discussed in this paper. If more than one gateways are discovered then need to select the best one on the basis of different parameters e.g., hop counts, traffic, congestion, load etc. Selecting best gateway is known as adaptive gateway discovery. So this paper is presenting an adaptive gateway discovery in MANET.

Ant like mobile agents (ALMA) helps in discover the gateway. The ants provide an optimal route to Internet gateways. Ants use routing algorithms as discussed in [14,10,9] and provide a route to the destination. Here destination is an Internet gateway. Ant uses the concept ant colony optimization for searching the food source. When the ant moves towards the food source then they release a special chemical substance called pheromone. Other ants follow the same path based on pheromone concentration. Pheromone concentration decreases with time and this decrement is known as Evaporation represented by ε. If any ant found a shorter path then this path will have higher pheromone concentration. So other ants will follow a path with maximum pheromone concentration. So in this way, an optimal path to the destination is discovered. If any other ant passes through the same path then pheromone concentration increases. This increment is known as reinforcement represented by ρ.

There are some problems with ant based routing:

- Discovered path may not fit for the situation.

- In a MANET, bandwidth is limited resource and high traffic in route may create congestion.
- Optimal route should be identified as early as possible.

The pheromone values are network state indicator. If any variation occurs because of link breakage or congestion (bottleneck) then pheromone values will change which results traffic flow variation. This variation can be helpful in routing procedure to load balancing though some other path or start to search for a new path. A new parameter Discovery Value (DV) is also proposed in this paper. If a routing algorithm discovered more than one gateway for any particular mobile node in MANET then selection of gateway will depend on DV. A gateway with minimum discovery value will be selected. This discovery value is a calculation of hop counts, stability, load, traffic and security parameters, etc. In this way selecting a suitable gateway is known as adaptive gateway discovery.
The remainder paper is organized as follows: Related work and literature reviews are discussed in section 2. In section 3 different ant pheromone evaluation models are discussed. The Proposed gateway selection scheme is described in section 4. Section 5 describes the Analytical model. Analytical proof of proposed scheme is given in section 6. Finally, section 7 gives the conclusion about the paper.

II. Related Work

Dorigo et al. [6] proposed the concept of ant system. They used ant as an agent and solved some problems like travelling salesman problem (TSP), the quadratic assignment problem and job scheduling problems, etc. They use the concept of pheromone concentration to find the path from source to destination. Yi et al. [14] showed that the ant system can be utilized for multicast routing in the MANET and proposed an improved ant based routing algorithm for MANET and compared with other routing protocols. After simulation he analyzed that ant based routing algorithm works better than proactive and reactive routing algorithms in some situations. Fernando Correia et al. [5] studied ants behavior based on pheromone concentration and simulate with MANET routing problems. After studying, he proposed some models for pheromone value evaluation in MANET. In this paper these models are used for gateway discovery. We have studied the evaluation of ant system and analyzed that ant related algorithms can easily solve any routing related problems.
Ayyadurai et al. [1] proposed a hybrid routing scheme which combines Ant and AODV, where AODV finds the path in local MANET and ALMA finds the path towards gateway. In this scheme, they used AODV which suffers from initial delay and they did not consider network load and stability factor to select appropriate gateway. Bin et al. [2] proposed an adaptive Gateway discovery scheme. In this approach, TTL values of gateway advertisement messages are adjusted dynamically according to the Internet traffic generated by the mobile nodes and their relative location from Internet Gateways with to which they are registered but they did not consider the stability factor. Gupta et al. [8] analyzed different pheromone evaluation models and used progressive pheromone reduction with maximum value (PPR-MV) in proposed gateway discovery approach. In case of multiple gateways, they used a Discovery Value to select an optimal gateway.
An efficient load aware gateway discovery approach was proposed by Srivastava et al. [13] where load is considered but path may be unstable and continuously changing intermediate routes. Pandey et al. [12] proposed congestion avoiding gateway selection scheme and used proxies to reduce the network overhead but path with less congestion may not be optimal path. Bo et al. [3] uses mobile IP to discover optimal gateway but mobile IP suffers from frequent handovers which is undesirable process. Yuste et al. [15] proposed an adaptive gateway discovery scheme where interval of emission of gateway advertisement is dynamically adjusted. This technique is shown to give better performance than conventional proactive gateway discovery scheme but it is not efficient.
Bouk et al. [13] proposed a gateway discovery algorithm on the basis of multiple QoS path parameters. They proposed two algorithms: first algorithm for reactive zone and second algorithm for proactive zone. In this case, we must identify the suitable zone in advance which is very difficult and complex. Zaman et al. [16] proposed an adaptive gateway discovery approach based on path load balanced. This approach primarily focuses on maximal source coverage. To cover maximum geographical area, this technique can provide better end-to-end delay and packet delivery ratio and in some specific cases only. Zhanyang et al. [17] proposed a simplified scheme for Internet connectivity where they used the concept of virtual MANET and consider that all Internet gateways are at fixed position but moving (dynamic) gateway node may exist.

III. Pheromone Evaluation Models

When the ants go to search food, they always want to search for a better (short) route. So initially they go in different (arbitrary) direction and release pheromones. Pheromones concentration (value) decrease with time and long route takes long time. So a route with the higher pheromone concentration is a better path. Other ants attract on higher pheromones. Finally best route is selected and other ants follow the same route for food collection. If this overall process will compare with a networking environment then food source is an Internet gateway and ants are data packets. More than one Internet gateways (like food sources) are also possible. There may be more than one path to reach the destination. In the networking environment virtual ants are considered so ants will release pheromone trail in the networks. Pheromone evaporates with time and reaches to 0 and if any other ant passes through the same route then it will reinforces (increases). In the Ant System (AS) model, route selection from source to destination (or next hop selection) is probabilistic. It uses heuristic selection based on pheromone values present in links. These pheromone values are calculated by formula:

$$\Phi_{j,k,t} = \varepsilon.\Phi_{j,k,t-1} + \sum_{i=1}^{n} \Delta\Phi^{i}_{j,k,t} \quad (1)$$

where $\Delta\Phi^{i}_{j,k,t} = \begin{cases} \frac{1}{d_{j,k}} & \text{if } (j,k) \in \text{path use by ant } i. \\ 0 & \text{otherwise.} \end{cases}$

where $\Phi_{j,k,t}$ is pheromone value of link between node *j* to node *k* at time *t*. $\Delta\Phi^i_{j,k,t}$ is the pheromone evaporation reinforcement value and $\varepsilon(0 < \varepsilon < 1)$ is evaporation rate. Reinforcement value is calculated upon the distance from node *j* to node k traveled by ant *i*. The total numbers of ants are *'n'*. This paper intended to identify the problems related to MANET, like frequent change in topology, broken link, congestion etc, on an initial stage and helpful in selecting the best path available. To achieve this goal, we will use four pheromone evaluation models for evaluating evaporation or reinforcement on the optimum network situation. These four pheromone evaluation models are given by Fernando Correia et al. [2] as follows:

- Ant system pheromone model
- Temporal active pheromone model
- Progressive pheromone reduction model
- Progressive pheromone reduction with maximum value model

A. Ant System Pheromone Model

In the equation (1), evaluation of pheromone value in AS model is presented. In this equation pheromone value is not depending on the previous network state, but in network environment routing always depends on the previous state. So the equation (1) is modified to:

$$\Phi_{j,k,t} = \varepsilon.\Phi_{j,k,t-1} + \sum_{i=1}^{n} \Delta\Phi^i_{j,k,t} \wedge \Phi_{j,k,t-1} \quad (2)$$

This model identifies pheromone values on three following different phases:

- **Learning phase:** In this phase, the pheromone value increases in a logarithmic manner until reaching a stationary value. The reinforcement of the pheromone value depends on the evaporation value and the traffic rate which flows through the path.
- **Maintenance phase:** In this phase, the pheromone value remains constant with small variations. Here, the reinforcement rate is equal to evaporation rate.
- **Evaporation phase:** When data transfer through the link is over then pheromone value decreases rapidly until reaches *0*. This condition may occur due to broken link or a traffic jam.

The Ant System pheromone model increases its pheromone intensity until reaches a stationary value when the link capacity has enough resources to transport the packets. It presents a fast growth rate to reach a stable value. When the data transfer session ends, or when in a presence of a bottleneck due link problem, the AS model will react to this and present a fast decrease of the pheromones. This model can be useful when fast response is required. However, on a network, changes on traffic transfer rate like packet jitter or a burst of packets could create a response similar to link bottleneck and give wrong information about the network state.

B. Temporal Active Pheromone (TAP) Model

The ant system pheromone model suffers from incorrect result in case bottleneck, because pheromone value decreases very fast when the path is idle. So the temporal active pheromones model, tries to solve this problem and manage a real behaviour of the pheromones with MANET routing problems. When real ants deposit a pheromone in the trail, the pheromone is active for a particular time. Similarly, in this model, even if the path is idle, pheromone value will active for a certain time. In this model, when the pheromone activity decrease, it will have a value equals to *0*.

$$\Phi_t = \begin{cases} 1(active) & t\_set < t < t\_set + \delta \\ 0(evaporation) & t > t\_set + \delta \end{cases} \quad (3)$$

$T_t = \sum \Phi_t$

where Φ_t and δ represents the single pheromone state at time *t* and the duration of activity respectively. The pheromone intensity of a link T_t is the addition of all deposited pheromones on the link. The evaporation phase is the time duration needed to stop the pheromone activity; hence it is equal to the pheromone life time. This model needs to simulate at each node which requires more memory and computational capacity at each node. Memory will store updated tables with pheromone values and timers deal with computational capacity is responsible to define the pheromone activity. The timers must be set to a well specified value according to the pheromone activity. On completion of data transfer, the reinforcement rate decreases to *0*. So network state can be analysed during the maintenance phase. If the network has sufficient resources to transfer the packet then pheromone variation will be about to zero. In case of broken links or congestion, the pheromone refreshes value will change.
The jitter and burst of data also affect the pheromone value because they related to the pheromone activity decrease rate. In this model, decrease rate is linear, so these effects can be neglected and the link can get its pheromone value when lost. Due to these reasons, the temporal active pheromone model is more stable to the network state changes than the Ant System pheromone model. This model will be slower to detect network problems than the AS model.

C. Progressive Pheromone Reduction (PPR) Model

The Progressive Pheromone Reduction model uses relatively less node resources in computation of pheromone intensity. The pheromone value depends on traffic flow of link. On increment of traffic flow, pheromone value also increases. But the increase rate directly depends on the link's capacity (bandwidth). Traffic variation can be analysed by pheromone increase rate. This model presents two valid phases: the maintenance phase and the evaporation phase. The maintenance phase is observed as long as the traffic flows through the link. The evaporation phase is progressive and happens when the traffic ceases its activity. There enforcement and evaporation formulas of PPR model are described as follows:

$$\Phi_t = \begin{cases} \Phi_{t-1} + \rho \\ \Phi_{t-1} - \varepsilon \end{cases} \quad (4)$$

where $\varepsilon = \begin{cases} 1 & \text{with link activity.} \\ \varepsilon * 2 & \text{without link activity.} \end{cases}$

Where ρ is the increase rate and Φ is pheromone value.When data transfer rate is constant, the pheromone value increases with same increase rate. When this increase rate changes, it means that the network is suffering from some problem. In PPR model, increase rate ρ is set to *1*.The pheromone value is evaporated after some constant time periodically. Every time when evaporation procedure is called, the pheromone value is decreased by evaporation factor ε. The value ε depends on traffic passing through link. If the packets are passing through the link then it represents the activeness of the link and ε is set to *1*, however, in case of traffic jam, ε updates its value every time the evaporation procedure is called and it represents the idle state of that link. Thus, we can say that minor traffic problems like packet burst, jitter or route repair procedure cannot affects the pheromone value, but if any link breaks during data transfer session then it will cause progressive pheromone evaporation and without reinforcement, the pheromone value decreases quickly to *0*.
The PPR model is a simple probabilistic model to evaluate the pheromone values. It represents the pheromone intensity variation to identify and classify the state of network, with a fixed scale of probability. The evaporation procedure, allows that small variations in the traffic rate, doesn't be notice in the pheromone global value and the path will continue to be marked as valid. When the data transfer through a route stops in the network, the pheromone activity through the route also stops and pheromone value periodically decreased to *0*. On stopping the pheromone activity, the route can be released.

D. Progressive Pheromone Reduction with Maximum Value (PPR-MV) Model

This model is about equivalent to the progressive pheromone reduction model, but there is a minor difference of deadline of pheromone value. In PPR-MV model, a maximum pheromone value is defined so it cant be greater than *MAX_VAL*. This model considers the two levels of pheromone evaluation. The first level is attached data session and second level is associated a link between nodes. The link state indicator is represented by the variation of the sum of all pheromones assign to the sessions present on that link. Link has sufficient resources to begin a new data session then the sum of pheromones will grow on a direct proportion of the number of sessions.
In a highly dynamic network like MANET, selection of appropriate neighbours is very important to data transfer. The selection of appropriate neighbour depends on pheromone value. Setting a limit on pheromone up to *MAX_VAL*, the variations in the pheromone intensity would not be sufficient to recognize the jitter, packet burst or congestion situations, but in case of traffic jam, the pheromone intensity will progressively decrease and returns to *0*. The refresh and evaporation formulas of PPR-MV models are defined as follows:

$$\Phi_t = \begin{cases} \Phi_{t-1} + \rho & \text{if } \Phi_{t-1} < MAX\_VAL \\ MAX\_VAL & \text{otherwise} \end{cases} \quad (5)$$

$\Phi_t = \Phi_{t-1} - \varepsilon$

where $\varepsilon = \begin{cases} 1 & \text{with link activity.} \\ \varepsilon * 2 & \text{without link activity.} \end{cases}$

PPR-MV model considers three phases to evaluate the pheromone intensity.These are learning phase, maintenance phase and evaporation phase. The learning phase is related to the session packet rate in the path and it ends when the pheromone value reach the maximum that has been selected. Maintenance phase represents that data transfer session is active and the maximum pheromone value is maintained. Similar to PPR model, small traffic rate variations are absorbed by the progressive evaporation procedure and the pheromone value shouldn't be almost the same. The evaporation phase is related to the end of data session, traffic jam and periodic decrement of pheromone value. When the data transfer completes its session, the pheromone progressive reduces to *0*. In this model, network state identification is difficult because of slow reaction to the network state changes. This model has ability to differentiate between active routes and idle routes.

IV. Proposed Gateway Discovery Approach with Ant

In our proposed scheme, each mobile node is considered as home of ants, where each data packet is considered as a single ant. The gateway node is equivalent to the food source of ants, where the ultimate goal of ants is to discover the optimal food source with optimal route. Similarly, in MANET, the ultimate goal is to discover the optimal gateway with optimal route. In the conventional algorithms minimum hop counts and load / congestion on route were considered to select optimal gateway. In the proposed algorithm we have used proper balance of hop count, load factor and stability factor. So we can get an optimal gateway with suitable route.

A. ANT based Routing Protocol

Ant-based routing algorithms have been explored by S. Marwaha, L. Hwang and D. Karthikeyan [11,9,10]. Ants are simply agents having the ability to move across the network. They move node to node randomly and update the routing tables of visiting nodes. Routing ants contain a history of visited nodes. On reaching a node, an ant updates the routing table of visited node and updates its history. When history size increases then overhead also increase, so history size should be well defined. Other than history size, the population of ants also affects routing overhead. In ant-based routing algorithm, each ant works independently and they cannot communicate with each other directly. In the conventional ant algorithms the next hop is selected randomly, but this paper implements no return rule [10] while selecting the next hop at a node because if the next hop selected is the same as the previous node then selected link will not provide an optimal route. The General behavior of ant is shown in Figure 1

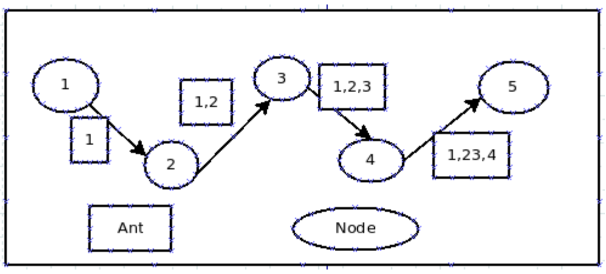

Figure. 1: Ant traversing the network and providing routing information to nodes

In our gateway discovery scheme, discovery time is reduced because ALMA takes the responsibility to discover the gateway and provides a highly dynamic approach to discover an optimal gateway in different conditions. It also provides automatic handover to another gateway while the running gateway becomes unavailable due to power off or any other problem. Each node frequently broadcasts ADV messages to its neighbour nodes. The ADV message helps in maintaining the neighbor list. This used for selecting the next neighbour node by the ants. Hybrid MANET follows dynamic topology of the network so connectivity of mobile nodes with other active mobile nodes and with gateway nodes is not certain. The dynamic topology of mobile nodes causes more delay in searching the route to a destination either in MANET orInternet.

The Ant colony optimization approach, i.e., ALMA is used to find the route to the gateway. The hybrid mechanism operates simultaneously when a route to the destination is needed by the source mobile node. In proposed scheme, the routing table of the mobile node is updated dynamically as shown in Table 1. The Internet gateway contains a routing table to update the information from the Internet.

Table 1: Entries in Routing Table of mobile node

Destination Address
Next Hop Address
Number of Hops
Pheromone Value
Pheromone Decay Time
Balance Index

B. Gateway Discovery Scheme

When a mobile node requires an Internet connection, it must discover an Internet gateway first. Initially mobile node uses a default prefix address to discover the gateway. The source mobile node initiates a gateway discovery process by sending forward ant(FANT) message to its neighbours. FANT maintains a history field of visited intermediate nodes. Each neighbor multicasts FANT until it reaches gateway node. This message passes through multiple intermediate nodes. The intermediate node receives FANT, update ants history and resend to a neighbour with maximum probability. Intermediate node uses FANT to update its routing table with pheromone value and decay time. On reaching FANT to Internet gateway, it checks whether it is a first ant with the same source. If any other ant reaches to the same gateway previously then drop this ant otherwise it will update the routing table of gateway with source node, next hop, hop count and pheromone value and then gets converted into backward ant (BANT) message.

The BANT packet contains the global IPv6 address of the gateway, pheromone value and pheromone decay time with the balance index, the network prefix of the gateway, the prefix length and lifetime. The BANT packet is unicast from the gateway to the source mobile node will pass through the list of intermediate nodes visited by the FANT packet. When BANT reaches to its source then update the source routing table with information generated from the link traversed. The link probability is calculated using pheromone value and the pheromone decay time given by ant. The balance index is a ratio of current gateway load and gateway capacity. The source mobile node receiving more than one BANT packet selects the adaptive gateway and a route by receiving maximum link probability, minimum hop count with lesser balance index. The source mobile node auto-configures its IP address after selecting the gateway using the prefix of the gateway with the suffix wireless interface address. The active intermediate nodes also preserve the updated adaptive information set by the BANT packet before the link probability reaches a minimum threshold value over time. On reaching the threshold value, the active intermediate mobile node generates a new FANT packet with the source mobile node address available from its routing table. The generated FANT packet updates the route to the gateway with either the new active node or the old active node for forwarding the data packets. The FANT and BANT packets explore and quickly reinforce the paths to the gateway. They also en- sure the previously discovered paths do not get saturated when the actual link fails.

The proposed algorithm uses mobile agent to reduce the route discovery latency with less convergence time. There are three different scenarios are considered to discover the gateway.

Scenario 1: All mobile nodes in the MANET have very limited resources i.e. memory, computational capacity, etc. In this scenario ant system pheromone model is the best model to discover the gateway. In the ant system pheromone model, when data trans- mission session ends then pheromone value rapidly decreases to zero. If data transmis- sion suffers from traffic congestion or delayed due to some other problem then this model assumes that the data transmission session is over and pheromone value de- creases to zero, hence this model suffers from incorrect result. This is the disadvantage of the ant system pheromone model.

Scenario 2: If all mobile nodes have sufficient resources, e.g. memory, computational capacity, timer and sufficient bandwidth. This model removes the problems of ant system pheromone model and pheromone value does not change rapidly. This model is more stable than the ant system pheromone model, but it is slower to detect the network problems.

Scenario 3: If some nodes have relatively less resources and gateway node is much far from the mobile node then PPR model and the PPR-MV model works efficiently. But the problem with PPR model is that, it doesnt have maximum pheromone threshold value so pheromone value may reach to infinite. PPR-MV model remove this problem by limiting maximum pheromone value to MAX_VAL. In the proposed algorithm, the PPR-MV model is used for calculating the pheromone values. This model gives the best result in normal conditions. The proposed algorithms for this scenario are as follows:

Algorithm: Gateway Discovery & Route Selection

Pre-assumption: Following assumptions have been made

- no return rule is considered in the algorithm.
- Every node has a table which contains the destination node, next hop, pheromone value and hop count for each neighbour.
- *index* represents the Index of last neighbor detail inserted in the table.

Main function for gateway discovery is given as follows:

Algorithm 1 Main Function

procedure
Initially set pheromone value for each link $\Phi_{i,j} = 0$
  if (S wants to send/receive data to/from internet host) **then**
    set S as a $source$
    $GW\_Discovery(source)$
  end if
  Select a gateway with minimum DV value
end procedure

The above algorithm is a main algorithm for gateway discovery. In this algorithm pheromone values of all links are initialized to zero. If any mobile node wants to use Internet then it calls *GW_Discovery(source)* algorithm where requesting node is source node. This *GW_Discovery (source)* algorithm will call further algorithms as per requirement and return *DV* value for each discovered algorithm. The main algorithm will select a gateway with minimum *DV* value. The main function/algorithm of the gateway discovery uses the following functions/algorithms:

Algorithm 2 GW_Discovery (source)

procedure
  initiate $FANT, fant\_id, index \leftarrow 0$
  $FANT[index++] \leftarrow fant\_id$
  $FANT[index++] \leftarrow source$
  for (each neighbour $N_s \in$ neighbour of source) **do**
    if $(Ns == GW)$ **then**
      $GW\_Discovered(Ns, index, FANT)$
    else
      $GW\_FRouting(Ns, index, FANT)$
    end if
  end for
end procedure

The source node initiates ant packet. This ant packet is in form of array. The first index of this ant contains *ant ID* and second index contains *source ID* of ant. After initialization it is broadcasted to all of its neighbours. When it reaches to any neighbour first of all it checks weather this node is gateway node or any intermediate node. If current node is gateway node then this algorithm will *IGW_Discovered (Ns, j, FANT)* otherwise *IGW_FRouting (Ns, j, FANT)* algorithm will be initiated. Here N_s is neighbour of source mobile node and *FANT* is forward ant.

Algorithm 3 $GW\_FRouting(MN, index, FANT)$

procedure
  if $(MN \in FANT)$ **then**
    drop packet and exit
  end if
  $FANT[index++] \leftarrow MN$
  for (each neighbour $N_{mn} \in$ neighbour of MN) **do**
    if $(N_{mn} == GW)$ **then**
      $GW\_Discovered(Nmn, index, FANT)$
    else if $(\Phi_{MN,N_{MN},t-1} < MAX\_VAL)$ **then**
      $\Phi_{MN,N_{MN},t} = \Phi_{MN,N_{MN},t-1} + \rho$
    else
      $\Phi_{MN,N_{MN},t} = MAX\_VAL$
    end if
    if $(t\%max_time == 0)$ **then**
      $\Phi_{MN,N_{MN},t} = \Phi_{MN,N_{MN},t-1} - \varepsilon$
      if (link is active) **then**
        $\varepsilon = 1$
      else
        $\varepsilon = \varepsilon * 2$
      end if
    end if
    update entries of Table of node
    $GW\_FRouting(Nmn, index, FANT)$
  end for
end procedure

Each mobile mode contains a table which has details of each visited ant. The above algorithm checks the table of intermediate mobile node. If it already contains the detail of visiting ant it means this ant packet is visited previously and ant packet will be dropped. Otherwise ant packet will update node ID in next empty slot and table of node will store detail about this ant. The first entry of table contains ID of source node, second slot will empty for gateway id, third slot holds selected neighbour node ID of mobile node and finally fourth entry stores the pheromone value for this neighbour mobile nose. The pointer *pos* points the next empty slot in table at intermediate mobile node. In this protocol, ant going towards gateway is known as forward ant. The current intermediate node will again broadcast the *FANT* to its neighbors until gateway node is discovered. If a particular link is activated and not used for a particular time *t_max* then pheromone value will be evaporated by given formula. If link is using again and again then pheromone value of link will reinforce its value until reached at *MAX_VAL*.

Algorithm 4 $GW\_BRouting(MN, N, index, BANT)$

procedure
  if (index==1) **then**
    print(path information is present in BANT)
    return BANT

else if ($\Phi_{BANT[index],BANT[index+1],t-1} < MAX\_VAL$) **then**
$\Phi_{BANT[index],BANT[index+1],t} = \Phi_{BANT[index],BANT[index+1],t-1} + \rho$
else
$\Phi_{BANT[index],BANT[index+1],t} = MAX\_VAL$
end if
if ($t\%max_t ime == 0$) **then**
$\Phi_{BANT[index],BANT[index+1],t} = \Phi_{BANT[index],BANT[index+1],t-1} - \varepsilon$
if (link is active) **then**
$\varepsilon = 1$
else
$\varepsilon = \varepsilon * 2$
end if
end if
update entries of Table of node
$index = index - 1$
$GW\_BRouting(BANT[index], N, index, BANT)$
end procedure

The above algorithm is also applied on intermediate mobile node but this algorithm is applies when gateway is discovered. This procedure applies in reverse direction i.e. from gateway node to source node so this ant packet is also known as *BANT*. The ant packet follows the route according to intermediate node entry present in *BANT* packet. The selected route is present in *BANT* packet. The *BANT* packet contains reverse path. The pointer *pos* points the current intermediate mobile node. The pheromone value reinforcement and evaporation is same as *IGW_FRouting (MN, N, j, BANT[])* algorithm.

Algorithm 5 $GW\_Discovered(GW, index, FANT)$

procedure
if ($GW \in FANT$) **then**
drop packet and exit
end if
initialize BANT
$balance\_index \leftarrow (current\_gateway\_load/gateway\_capacity)$
$DV \leftarrow Hop * F_H + balance\_index * F_L + F_S/RS$
$FANT[index] \leftarrow DV$
for ($p = 0$ to $index$) **do**
$BANT[p] \leftarrow FANT[p]$
end for
$N \leftarrow index$
if ($\Phi_{GW,FANT[index-1],t-1} < MAX\_VAL$) **then**
$\Phi_{GW,FANT[index-1],t} = \Phi_{GW,FANT[index-1],t-1} + \rho$
else
$\Phi_{GW,FANT[index-1],t} = MAX\_VAL$
end if
if ($t\%max_t ime == 0$) **then**
$\Phi_{GW,FANT[index-1],t} = \Phi_{GW,FANT[index-1],t-1} - \varepsilon$
if (link is active) **then**
$\varepsilon = 1$
else
$\varepsilon = \varepsilon * 2$
end if
end if
update entries of Table of node
$index = index - 1$
$GW\_BRouting(BANT[index], N, index, BANT)$
end procedure

The above algorithm *IGW_Discovered (GW, j, FANT [])* used when gateway is discovered by *FANT* packet. In the first stage it also checks for duplicate discovery. If *FANT* is visited previously then simply drop this packet otherwise initialize *BANT* packet. Gateway node calculates balance index and Discovery Value. Discovery value is calculated using stability factor in terms of pheromone value, hop count in terms of number of intermediate visited node and balance index. We decided fraction of each parameter in simulation part. So, gateway node will calculate discovery value and put it into last slot of *FANT* packet. When multiple *BANT* packets received at source node then source node selects only one path which has minimum *DV*. After calculating *DV* at gateway node, *FANT* will convert to *BANT* and all values with index copied to *BANT* packet. The pheromone value reinforcement and evaporation is same as *IGW_FRouting* algorithm. Gateway node also contains a routing table and stores all information same as intermediate mobile node. The gateway node table has one extra field i.e. information about discovery value. At the end, it calls *IGW_BRouting* algorithm until BANT reached at source mobile node.

V. Analytical Model

Through our analytical model, the proposed approach is proved analytically. Each node has a communication range *R*, where it can communicate with other node i.e. neighbour node. In the proposed scheme, a pheromone value $\Phi_{i,j}$ is assigned to every link between node *i* and node *j*. When ant passes through this link, the pheromone value is increased by reinforcement factor. The pheromone value decreases with some value after every *t* time. The ultimate goal of this scheme is reaching at the gateway node. The ant scheme is a probabilistic approach so next neighbour should be chosen with highest probability. The Equation (6) computes the total probability of the link towards the gateway *g*. The mobile agent located at particular node uses pheromone value $\Phi_{i,j,g}$ to calculate the link probability $P_{i,j,g}$ towards the gateway *g*. The specific next hop neighbour is chosen according to the probability distribution in each link.

$$P_{i,j,g} = \begin{cases} \frac{(\Phi_{i,j,g}+T)^S}{\sum_{j=1}^{N_i}(\Delta\Phi^i_{i,j,g}+T)^S} & \text{if } j \in N_i \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

In the above equation, *S* and *T* are pheromone sensitivity value and threshold value respectively. $S \geq 0$, used to modulate the differences between pheromone amounts present in link probability. The value $S < 1$ evaporate the link, while $S > 1$ will reinforce the differences between links. The value *S* equal to *1* gives the normal form. If $T \geq 0$ larger then large amounts of pheromone will be present before an appreciable effect will be seen in the link probability. The link probability $P_{i,j,g}$ of the node i fulfills the constraint in giving transition probabilities as in Equation 7.

$$\sum_{j \in N_i} P_{i,j,g} = 1, i \in [1...N] \tag{7}$$

During the route finding process to the gateway, mobile agents deposit pheromone on the edges. The pheromone concentration is varying from one edge to another between the nodes connecting them by an amount $\Delta\Phi$. The pheromone value changes at the edge *e(i, j)* when mobile agents moving from node *i* to node *j* are given in Equation 8.

$$\Phi_{i,j,g} = \Phi_{i,j,g} + \Delta\Phi \tag{8}$$

The selection decision gives the fact that the path length between the nodes connecting the gateway is less than R and the route selected is stable. The various symbols used in this analytical model are briefly described in Table 2.

Table 2: Description of Symbols used

Symbol	Description
$\Phi_{i,j}$	Pheromone value of edge $e(i,j) \in E$
$P_{i,j}$	Probability value of edge $e(i,j) \in E$
V_s	Source node (vertex)
R	Mobile Nodes communication range
T	Pheromone Threshold value (constant)
S	Pheromone Sensitivity value (constant)
E	Set of all edges (links) in wireless network
N_i	Set of Neighbors of node i
N	$n = \|V\|$ number of nodes in the network
V_g	Gateway node (vertex)

A. Route Maintenance

The route maintenance algorithm is responsible for maintaining the same established route to the gateway or establishing any other better route. Ants continuously move from one node to another node and pheromone value evaporate after time *max_time*. When a data packet passes through node *i* toward the gateway *g* to a neighbour node *j*, it increases the pheromone value if link *e(i,j)* by $\Delta\Phi$ i.e. represented in equation 8. The evaporation process is represented in equation 9 given below:

$$\Phi_{i,j} = (1-q)\Phi_{i,j}, q \in [0...1] \tag{9}$$

In both the cases pheromone value of the route keeps on changing. In this case new route with minimum *D-V* may discover but continuously route cannot be changed because it will represent the instability of the route. The new pheromone value will be compared with the existing pheromone value and if new value is at least 20 percent less than the old pheromone value then the route will be updated. The proposed algorithm for route maintenance is given as follows:

Algorithm 6 Gateway and Route maintenance

Pre-assumption: Time t will increase at constant rate

procedure
  set $t = 0$
  for (each link $L_{i,j,g} \in$ network) **do**
    if (ANT passes through $L_{i,j,g}$) **then**
      $\Phi_{i,j,g} \leftarrow \Phi_{i,j,g} + \Delta\Phi$
    end if
    if ($max\_time\%t == 0$) **then**
      $\Phi_{i,j,g} \leftarrow (1-q)\Phi_{i,j,g}$
      set $t = 0$
    end if
  end for
  calculate DV periodically based on information given by ANT
  if $(DVnew < (DVold0.2 * DVold))$ **then**
    update route and Internet gateway according DV new and ANT
  end if
end procedure

The algorithm represents the route maintenance procedure from source node to gateway node. If any ant passes through the same route then pheromone value of this route increases by reinforcement constant on other hand if no ant follows the same route for a particular time then pheromone value decreases with evaporation factor. The DV depends on pheromone value and other factors. During data transfer if ant finds new route with minimum discovery value then we should change the route but in this way discovery process will be unstable and we need to handover the connection again and again. To manage the stability of discovery process we considered a new logic, if newly discovered route has 20% less DV then only route will change otherwise route will remain same. If any node receives a duplicate packet, it sets the DUPLICATE_ERROR flag and sends the packet back to the previous node. The previous node deactivates the link to this node then any data packet will not sent to this direction.

B. Connection Recovery

In the proposed scheme, network is considered as dynamic in nature. So any node may join or leave the network any time. If node moves from the network then connection to the gateway may be lost. This may happen due to link failure, bandwidth limitation, node movement or power failure. In this case connection recovery mechanism is required. When connection is lost, link probability of related nodes goes to zero, i.e. identified by neighbour nodes. Then neighbour node again establishes the connection with maximum link probability and connection to the gateway is recovered.

VI. Result and Discussion

To evaluate the proposed scheme, we have considered an ad hoc network. In this network, we have evaluated some results on the basis of variable number of mobile nodes. On the basis of result of analytical study, we observed that ant scheme works better than proactive and reactive gateway discovery schemes. Figure 2 and Figure 3 represent the comparative analysis of the packet delivery ratio and end to end delay respectively.

A. Packet Delivery Ratio (PDR)

It is the ratio of total data send from source and received at the destination. In this case, the mobile node is the source and gateway is the destination when data is uploading. In case of downloading, the mobile node is the destination and gateway node is the source. So we have to consider both the cases. When simulation starts then FANT packets broadcasted in all directions. In this case, less number of FANT packets are received at proper destination. So packet delivery ratio is relatively lesser than proactive and reactive gateway discovery scheme. When first BANT message received at source node then connection has been established. After establishing the connection, the probability of losing the packets gets reduced. Figure 2 represents the result of the comparison of ant scheme with proactive and reactive scheme and proved that ant scheme works better than proactive and reactive scheme, in terms of packet delivery ratio.

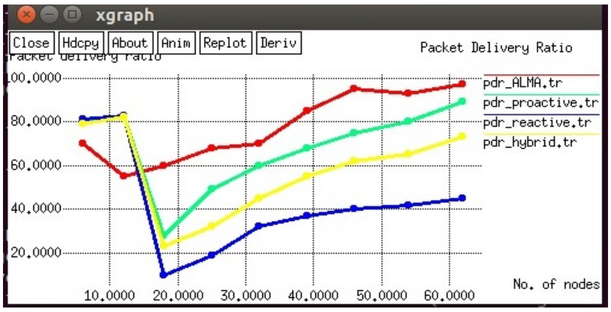

Figure. 2: Packet Delivery Ratio

B. End-to-End Packet Delivery Latency

End to end delay is the time difference between data send from source and received at the gateway. This includes all delays due to buffering during the route discovery time, queuing at the interface queue, and retransmission latency at the MAC layer, as well as propagation and transmission time. In initial stage, proper path is not established. So, ants pass through random path. In this case end to end delay increased, but after finding the optimal path, packet directly received as destination without much delay. As time increases, source node knows about all paths. So, in case of connection breakage, it establishes another optimal path rapidly. Figure 3 describes the comparative analysis of end to end delay with proactive and reactive gateway discovery schemes and shows that on increasing time, end to end delay get decreased.

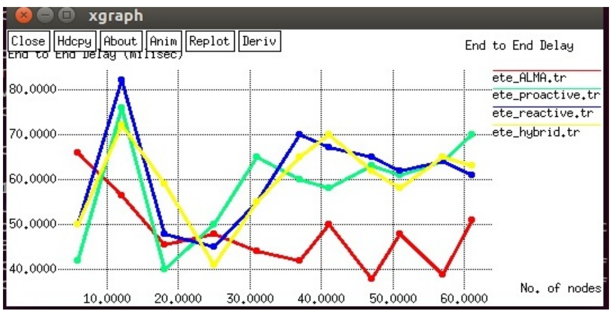

Figure. 3: End-to-End delay

VII. Conclusions and Future Directions

In this paper, four models for pheromone value computation are discussed. Each model has different characteristics, so each model can be used in some specific condition. The Pheromone variation, used in this paper is an indicator of network state. The proposed approach overcomes the shortcomings of other existing gateway discovery protocols and provides the optimal route to the Internet gateway with less discovery time, high packet delivery ratio and also minimizes end to end delay. These improvements are obtained at the cost of slightly higher average overhead. This is possible with the help of a new metric i.e. discovery value. This new metric combines hop count, stability factor, congestion and load on the gateway. A route with minimum discovery value has been selected.

The future work can involve generation of ants in the network, as per requirement. Loss of ants should be implemented in certain conditions. There is a need of adding inter-agent communication and intelligence to the ant agents during route discovery.

References

[1] V. Ayyadurai, R. Ramasamy. Internet Connectivity for MANET Using Hybrid Adaptive Mobile Agent Protocol, *International Arab journal of information technology*, V (1), pp. 25-33, 2008.

[2] S. Bin, S. Bingxin, L. Bo, H. Zhonggong, Z. Li. Adaptive gateway Discovery Scheme for Connecting Mobile Ad Hoc Networks to the Internet. In *Proceedings of the IEEE International conference on wireless communications, networking and mobile computing*, pp. 795-799, 2005.

[3] L. Bo, Y. Bin, S. Bin. Adaptive Discovery of Internet Gateways in Mobile Ad Hoc Networks With Mobile IP-based Internet Connectivity. In *Proceedings of the 5 th IEEE International conference on wireless communications, networking and mobile computing*, pp. 1-5, 2009.

[4] S. H. Bouk, I. Sasase, S. H. Ahmed, N. Javaid. Gateway Discovery Algorithm Based on Multiple QoS Path Parameters between Mobile Node and Gateway Node. In *Journal ofCommunication and Networks*, XIV, pp. 434-442, 2012.

[5] F. Correia, V. J. Lobo, T. Vazao. Models for pheromone evaluation in ant system for mobile ad hoc networks. In *Proceedings of the First IEEE International Conference on Emerging Network Intelligence*, pp. 85-90, 2009.

[6] M. Dorigo, A. Colorny, V. Maniezzo. Ant system: optimization by a colony of cooperating agents. In *IEEE Transactions on Systems, Man, and Cybernetics, Part B*, XXVI (1), pp. 29-41, 1996.

[7] N. K. Gupta, A. K. Gupta, R. Kumar. An Adaptive Gateway Discovery using Mobile Agent in MANET. In *International Journal of advanced Research in Computer Science and Software Engineering*, IV (2), pp. 4-10, 2014.

[8] N. K. Gupta, R. Kumar, A. K. Gupta, P. Srivastava. Ant Pheromone Models Based Gateway Selection in MANET. In *Proceedings of the 6 th International conference on Innovations on Bio-Inspired Computing and Applications (IBICA)*, CCCXXIV, pp. 297-311, 2014.

[9] L. Huang, H. Han, J. Hou. Multicast Routing Based on Ant System. In *Applied Mathematical Sciences*, I, pp. 2827-2838, 2007.

[10] D. Karthikeyan, M. Dharmalingam. Ant based intelligent routing protocol for MANET. In *Proceedings of the IEEE International Conference on Pattern Recognition, Informatics and Mobile Engineering (PRIME)*, pp. 11-16, 2013.

[11] S. Marwaha, C. K. Tham, D. Srinivasan. A Novel Routing Protocol Using Mobile Agents and Reactive Route Discovery For Ad Hoc Wireless Networks. In *Proceedings of the IEEE International Conference on Networks*, pp. 311-316, 2002.

[12] A. Pandey, N. Gupta, A. Agarwal, R. Kumar, J. Prakash. Congestion Avoiding Gateway Discovery and Selection Scheme for MANET. In *Proceedings of the Eighth International Conference on Computer Communication Network (ICCN)*, pp. 39-47, 2014.

[13] P. Srivastava, R. Kumar. An Efficient Load-Aware Gateway Discovery for Internet Connectivity in MANET. In *Proceedings of the Eighth International Conference on Computer Communication Network (ICCN)*, pp. 87-95, 2014.

[14] Z. Yi, L. Y. Chun. An improved ant colony optimisation and its application on muticast routing problem. In *International Journal of Wireless and Mobile Computing*, V (1) pp. 18-23, 2011.

[15] J. Yuste, A. Trivio, F. D. Trujillo, E. Casilari. Improved Scheme for Adaptive Gateway Discovery in Hybrid MANET. In *Proceedings of the 30 th IEEE International Conference on Distributed Computing System Workshop (ICDCSW)*, pp. 270-275, 2010.

[16] R. U. Zaman, K. U. R. Khan, A. V. Reddy. Path load balanced Adaptive Gateway Discovery in integrated Internet-MANET. In *Proceedings of the Fourth IEEE International Conference on Communication Systems and Network Technologies (CSNT)*, pp. 203-206, 2014.

[17] X. Zhanyang, H. Xiaoxuan, Z. Shunyi. A Simplified Scheme of Internet Gatyeway Discovery and Selection for MANET. In *Proceedings of the 5 th IEEE International Conference on Wireless Communication, Networking and Mobile Computing*, pp. 1-4, 2009.

[18] T. Zhi, Z. Hui. An Improved Ant Colony Routing Algorithm for WSNs. In *Journal of Sensors*, MMXV Article ID 438290 pp. 4, 2015.

[19] R. U. Zaman, K. U. R. Khan, A. V. Reddy. Weighted Load Balanced Adaptive Gateway Discovery in Integrated Internet MANET, in *Distributed Computing and Internet Technology*, R.Natrajan, G. Barua and M. R. Patra (eds.), Springer International Publishing, Switzerland, 2015.

Author Biographies

Naveen Kumar Gupta received his B. Tech degree in Computer Science and Engineering from Inderprastha Engineering College Ghaziabad (U.P.), India in 2011 and M. Tech in Information Technology from Madan Mohan Malaviya University of Technology Gorakhpur (U.P.), India in 2014. Presently he is pursuing PhD from Motilal Nehru National Institute of Technology Allahabad (U.P.), India since July, 2015. He also worked as Assistant Professor at SR Group of Institutions Jhansi (U.P.), India from August-2014 to July-2015. He has published five research papers in International and one in National Journal/ conferences. He has completed his M. Tech thesis on the topic Adaptive Gateway Discovery in Mobile Ad hoc Networks. His main research interest lies in Wireless Sensor Networks and Ad hoc Routing protocols.

Dr. Deepak Gupta is workingas Assistant Professor in the Department of mathematics at SR Group Of Institutions, Jhansi since 2006. He was awarded Ph.D in Mathematics from Bundelkhand University Jhansi in the year 2013 under the guidance of Anjana Solanki. He work in the area of Non-Markovian queueing model and Fuzzy logic.

Dr. Rakesh Kumar received his B.E. degree in Computer Engineering from M.M.M. Engineering College Gorakhpur (U.P.), India in 1990, M. E. In Computer Engineering from S.G.S. Institute of Technology and Science, Indore, India in 1994 and Ph D in Computer Engineering from Indian Institute of Technology, Roorkee, India in June 2011. Presently he is an Associate Professor in the department of Computer Science and Engineering at Madan Mohan Malaviya University of Technology Gorakhpur since January 01, 2006. He has supervised a large number of M Tech Dissertations and also supervising four Ph D students. He has published a large number of research papers in International and National Journals and conferences of high repute. He is a recipient of best research paper award and also principal investigator of a major research project ongoing since June 2013 sanctioned for three years from University Grant Commission, India. He is a life member of CSI, ISTE and also a Fellow of IETE and IE (India). His main research interests lies in Mobile Ad hoc Routing, Quality of Service Provisioning, MANET-Internet Integration and Performance Evaluation.

Amit Kumar Gupta received his B. Tech degree in Computer Science and Engineering from Institute of Technology and Management Meerut (U.P.), India in 2012. Presently he is a Software Engineer in Image Enterprises, Gurgaon, (Haryana), India. He has published four research papers in International and one in National journals / conferences. His main research interest lies in Mobile Ad hoc Routing protocols and security issues.