

# A Timestamp-Based Adaptive Gateway Discovery Algorithm for Ubiquitous Internet Access in MANET

Prakash Srivastava and Rakesh Kumar

**Abstract** Internet gateways are used for integration of mobile ad hoc network (MANET) with Internet to increase its usability. Mobile nodes in MANET need to discover an Internet gateway to obtain Internet connectivity. Existing gateway discovery approaches such as reactive, proactive, and hybrid suffer from low network throughput and performance trade-off. In the proposed gateway discovery scheme, proxy nodes are utilized to reduce network overhead as well as dynamically adjust proactive area of gateways according to traffic load on a gateway. The gateway selection scheme uses a timestamp factor besides hop count and queue length for selecting an optimal Internet gateway. The performance of the proposed approach is analyzed through simulation on the basis of routing overhead and gateway discovery time. Results show that our approach has been found outperforming to existing approaches.

**Keywords** Mobile ad hoc network · TTL (time-to-live) · Adaptive gateway discovery · Timestamp

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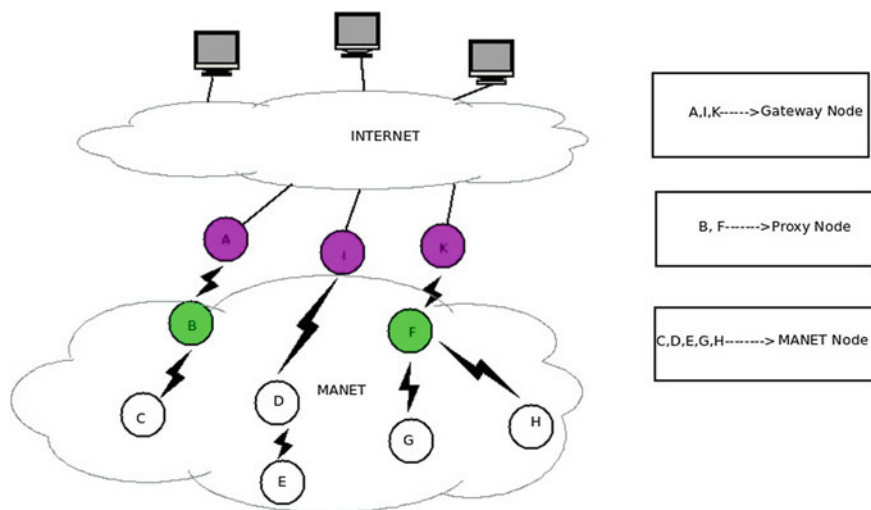
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## 1 Introduction

Mobile ad hoc network [1] and the fixed networks such as Internet are integrated to extend network coverage and also to enhance usability of such networks. The architecture of such network differs from Internet as it makes assumptions of various sorts on the structure, dynamic topology, and communication patterns. Due to these differences, integrating different networks to form a hybrid network is a challenging issue. Internet gateway acts as a bridge between a MANET and the Internet for achieving integration. Communication of mobile devices such as laptop, PDA, smart phones in an ad hoc network and a fixed device in Internet needs changes in MANET routing protocol such as AODV, DSR. The challenge in integration of MANETs to Internet originates from the need to inform mobile nodes about available Internet gateways. In this scenario, there is a great challenge of making an optimal consumption of scarce network resources such as bandwidth battery power. In the proposed approach, proxied adaptive is used for MANET-Internet integration in which some nodes in the MANET act as proxy nodes to minimize the load on gateway and also reduce network overhead as depicted in Fig. 1.

The organization of the rest of the paper is as follows. Related work about MANET-Internet integration and various gateway discovery approaches are described under Sect. 2. The proposed gateway discovery scheme is presented in Sect. 3. Section 4 presents performance evaluation using simulation. Finally, conclusions along with directions of future work are presented in Sect. 5.



**Fig. 1** MANET-Internet integration strategy

## 2 Related Work

Hamidian et al. [2] proposed a gateway discovery scheme for Internet access to mobile ad hoc networks. The AODV routing protocol used in the MANET domain was modified. They devised three gateway discovery approaches, namely reactive, proactive, and hybrid for Internet connectivity. All these three approaches are based on single hop count metric for gateway discovery.

A load-adaptive gateway discovery proposal was proposed by Park et al. [3], which resizes proactive gateway advertisements range dynamically and reduces gateway acquisition latency. For adjusting this area dynamically, access gateway should know the information like number of source nodes and network nodes that requires Internet connectivity and size of the network. This approach takes into account the load of the network while calculating the TTL value dynamically, but the problem of gateway advertisement messages periodicity are not addressed.

The existing solution for MANET-Internet integration was analyzed by Nordstrom et al. [4] but flexibility and robustness were found lacking. Authors come to the conclusion that interconnection scheme's inability to express indirection is the cause for routing failure. Another problem concerns state replication in which a route update does not succeed to replicate all the routing state required to forward packets to a gateway. The proposed scheme when combined with AODV enhanced the packet delivery ratio up to 20% which is shown through simulation.

Zaman et al. [5] discussed two important issues in MANET-Internet integration. First, the path load balancing during communication of mobile nodes with gateways. Second, mobile nodes register with a gateway before communication begins. This approach is focused on combining adaptive gateway discovery, balancing path load mechanism, and maximal source coverage [6] scheme. The simulation results show the improvement in normalized routing load but it does not show any significant improvement in packet delivery ratio and end-to-end delay as compared to other approaches.

Yuste et al. [7] proposed an adaptive gateway discovery scheme in which the frequency of gateway advertisement ( $T$ ) 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.

## 3 Proposed Gateway Discovery Mechanism

We call our scheme as timestamp-based proxy adaptive gateway discovery algorithm. This approach takes the benefit of local information provided by proxy which is gained by some mobile nodes in the network [8]. Since, adaptive gateway discovery scheme creates a reactive and proactive zone, gateway advertisement

**Fig. 2** Modified gateway advertisement (GW\_ADV) message format

Type	Reserved	Prefix size	Hop Count
Broadcast ID			
Destination IP Address			
Destination Sequence Number			
Source IP Address			
Lifetime			
Q			
N			
T			

(GWADV) does not require flooding across whole network [9]. Nodes which are intermediate acting as proxy in proactive zone border reply using a gateway reply (GW\_REP) unicast to the originator and thereby reducing the overhead.

Majority of gateway selection schemes/approaches use minimum number of hops to select an optimal gateway [10–12], consequently under high traffic load, the nearest Internet gateway suffers from bottleneck, besides there is also some nodes which are congested along the gateway route. In our scheme, we introduce an additional metric, i.e., timestamp factor ( $T$ ) as shown in Fig. 2 in gateway advertisement message (GW\_ADV) format. Now gateway selection metric takes into account four metrics, and therefore now the composite metric  $gc$  is computed with the help of modified Eq. 1.

$$gc = hc + T + (N/N + 1) + (Q/Q + 1) \quad (1)$$

The source node always selects gateways having high response time, and the traffic is distributed evenly among other gateways resulting in lower chances of collision and packet loss due to high congestion.

### 3.1 Algorithm for Calculation of Proactive Area

```

1. Initialize
2. ttl ← A.η/N.2P
   n(Δt) n(Δt)
3. Load, ρ = ∑ λi . ∑ ζi
   i=1 i=1
   // Event advertisement timer expires
4. if ttl > 0 then
5. GW_REP.src = this gateway;
6. GW_REP.dst = broadcast;
7. GW_REP.ttl = ttl;
8. GW_REP.T=current time;
```

```

9. send GW_REP ;
10. end if //Event receive GW_REQ (Route request)
11. set-up reverse route;
12. GW_REP.src = this_gateway;
13. GW_REP.T=current_time;
14. GW_REP.dst = GCREQ.src;
15. send GW_REP ; //Event load estimation timer expires
16.  $\gamma_{max} = \rho + 0.005$ ;
17.  $\gamma_{min} = \rho - 0.005$ ;
18. Estimate new load as

$$\rho = \sum_{i=1}^{n(\Delta t)} \lambda_i \cdot \sum_{i=1}^{n(\Delta t)} \zeta_i$$

19. If  $\rho > \gamma_{max}$  then  $t_{tl} \leftarrow t_{tl} + 1$ ;
20. If  $\rho < \gamma_{min}$  then  $t_{tl} \leftarrow t_{tl} - 1$ ; //Event receive DATA
21. communicate with DATA.src;

```

### 3.2 Algorithm for Congestion Mitigating Gateway Selection and Discovery Scheme

```

1. Initialize
2.  $G \leftarrow \emptyset$ ; where G set contains tuple of form (g,T) //g←set of gateways // T←Timestamp factor
3. last_reply_time  $\leftarrow 0$ ; // Event route to Internet lost
4. if (current_time - last_reply_time)  $\geq$  time between periodic GCREP then
5. GW_REQ.src = this_node;
6. GW_REQ.dst = broadcast;
7. send GW_REQ ;
8. end if //Event receive GW_REQ (Route request)
9. setup reverse route;
10. if  $G \neq \emptyset$  then
11. let g is the selected gateway from this node according to metric gc;
12.  $gc = hc + T + (N/N+1) + (Q/Q+1)$ 
13. GW_REP.src = g;
14. GW_REP.T=current_time - T of selected g from (g,T);
15. GW_REP.dst = GCREQ.src;
16. GW_REP.proxy = yes;
17. send GW_REP ;
18. else

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```

19. forward GW_REQ // Event receive GW_REQ
20. Set up forward route
21. if GW_REQ.dst ≠ this_node then
22. forward GW_REQ
23. if GW_REQ.dst=broadcast then
24. last_reply_time = current_time
25. end if
26. end if
27. G ← G U GW_REQ.src;
28. T ← current_time - GW_REQ.T;
29. schedule active gateway timer for GW_REQ.src;
    // Event active gateway timer expires
30. G ← G/{g, T}; //Event data transmit
31. if G ≠ ∅ then
32. Select a g which belongs to G such that metric gc is minimum
33. gc =T+ hc + (N/N+1) + (Q/Q+1)
34. send data
35. else
36. send GW_REQ
37. end if

```

## 4 Performance Evaluation

The proposed approach is implemented using NS-2 simulator (NS 2.34 version). For performance comparison of our proposed approach with existing ones, common simulation parameters are given as per Table 1 [13–16].

### 4.1 Performance Metrics

The following performance metrics have been used.

- **Routing Overhead:** The total number of control messages, including gateway discovery generated is called routing overhead. It is computed by the formula given below:

$$R_{\text{overhead}} = \sum_{i=1}^n \text{Overhead}_i$$

**Table 1** Simulation parameters

Parameters	Values
Number of mobile nodes	15 and 60
Number of sources	10, 20, 30, 40 and 50
Wireless transmission range	250 m
Number of gateways	4
Number of hosts	2
Topology size	1200 × 800 m
Traffic type	CBR
Packet size	512 bytes
Packet sending rate	5 packets/s
Mobility model	Random waypoint
Length of interface queue	50 packets
Link level layer	IEEE 802.11 DCF
Interval between successive GW_ADV advertisement	5 s
Speed of a mobile node	20 m/s
Simulation time	500 s

- **Gateway Discovery Time:** The times required to search and discover a gateway is known as gateway discovery time. It is computed by the formula given below:

$$T_{\text{GWD}} = \text{searching time} + \text{delay latency}.$$

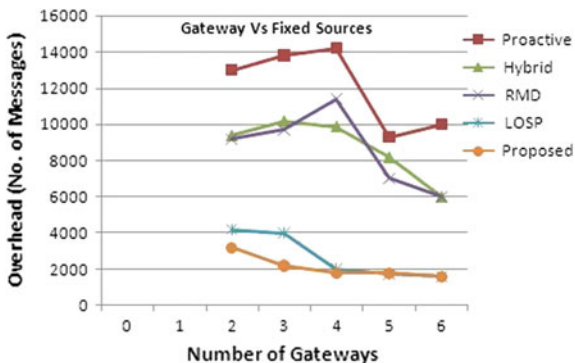
## 4.2 Results and Discussion

The routing overhead in case of our proposed scheme as shown in Fig. 3 shows less number of routing overhead messages as compared to other gateway discovery schemes due to proxy and less congestion due to timestamp factor which causes less packet drops and less retransmission, consequently less routing overhead.

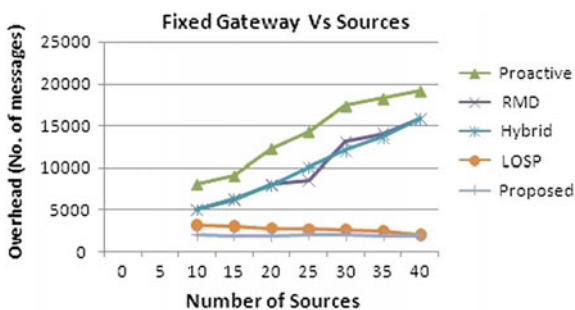
If we are considering the fixed scenario of four gateways and increasing number of source nodes, the overhead caused by our proposed scheme in terms of number of message is less compared to other gateway discovery schemes as displayed in Fig. 4. The scalability of our proposed scheme is better due to our unique congestion mitigating scheme and integration of proxy node with gateways which does not cause overload situation on gateways.

The proactive algorithm shows less gateway discovery time in short time span and bad performance for longer time interval. Interval time is the time between successive solicitations. The discovery time for RMD scheme is relatively constant, as the frequency of solicitations depends on mobility condition. Our proposed gateway discovery scheme performs better in terms of gateway discovery time even in higher time intervals, and it is clearly reflected in Fig. 5.

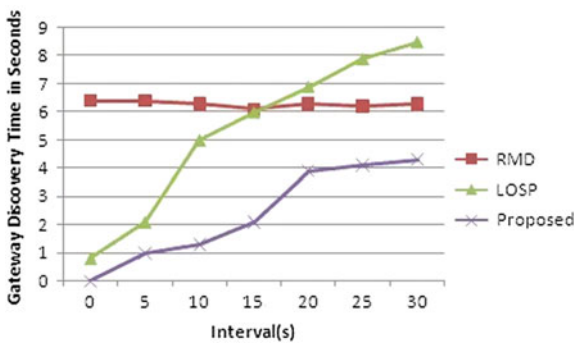
**Fig. 3** Routing overhead when there is fixed number of sources



**Fig. 4** Routing overhead when there is fixed number of gateways



**Fig. 5** Gateway discovery time





## 5 Conclusions and Future Scope

A new proxied adaptive algorithm is designed which exploits the traffic load on the gateway to dynamically adjust the proactive range. Mobile nodes use timestamp value which is set by a gateway in GW\_REP message to calculate the composite metric  $gc$  and thus select an optimal gateway with least congested route. Our proposed protocol provides two benefits. First, it is scalable when the number of gateways and source node increases. Second, it can also help a node choose an efficient gateway among multiple available gateways with highest response time with lower packet loss due to congestion. The future works include incorporation of security mechanism to our modified proxy gateway discovery scheme. Further, improvement may also include calculation of more accurate optimal proactive zone.

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