IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 3, No 3, May 2012
ISSN (Online): 1694-0814
www.IJCSI.org

QoS based Analysis of Proxied Adaptive Gateway Discovery Scheme for Mobile Ad hoc Networks

K.Palani[1], P.Ramamoorthy[2]
[1] Assistant Professor, Department of Computer Science and Engineering,
Tamilnadu College of Engineering, Coimbatore, Tamilnadu, India.
[2] Dean (Academic), Sri Shakthi Institute of Engineering and Technology,
Coimbatore, Tamilnadu, India.

Abstract

One of the most important aspects a effecting the overall QoS performance of hybrid mobile ad hoc networks is the efficient discovery of Internet gateways. So many previous papers addressed the problem of interconnecting Mobile Ad Hoc Networks (MANET) to the Internet, via one or more attachment points called gateways. The protocol employed to discover available gateways and set up routes to the Internet should not incur in a big overhead, due to the insufficient resources of ad hoc networks. However, previous works do not meet this requirement either when the number of traffic sources or available gateways increases. In our work, we develop a QoS based analysis of Proxied Adaptive gateway discovery scheme which dynamically adapts its behavior depending on the number of active traffic sources which are in the MANET. This approach employs intermediate nodes which make use of available local information (proxies) to further reduce the control overhead, and provide a high packet delivery ratio using NS2 Network Simulator.

Keywords: *QoS based PAGD, Hybrid MANET, Maximum Source Coverage, Internet gateways, Control overhead.*

1. Introduction

Although ad hoc networks can operate in a standalone fashion without any pre-established infrastructure, they are envisioned to play an important role in future mobile service provider deployment. Hybrid MANETs attached to the Internet through one or more gateways can be used to easily extend the coverage of the Internet access for certain areas or temporary events.

Many research efforts have been conducted during the last years to provide a mechanism for the discovery of available gateways and the creation of routes to the Internet. In addition, when ad hoc nodes want to communicate with hosts in the Internet, they must first acquire a globally routable IP address1. The gateways are responsible for providing ad hoc nodes with valid subnet prefixes, in order to allow them to auto-configure their own global IP addresses. Many of these issues are being studied within the AUTOCONF Working Group [6] of the Internet Engineering Task Force (IETF). However, the gateway discovery function has turned out to be one of the most important aspects affecting the overall performance. Thus, we focus our paper on the gateway discovery function.

Previous gateway discovery schemes behave either proactively or reactively. In proactive schemes, gateways periodically flood the network with prefix information. In reactive schemes nodes flood a request when needed, and gateways reply with prefixes. These schemes are only suitable for certain scenarios. In particular, a proactive scheme does not scale as the number of gateways increases, and reactive ones do not scale as the number of sources increases.

To achieve a better scalability and a minimum control overhead, we propose a hybrid approach in which gateways send out periodic messages to nodes at a certain distance, while those further away operate on demand. The scope of the advertisements is dynamically set depending on the network conditions. In addition, to further reduce the overhead, intermediate nodes are allowed to reply on behalf of the gateways if they know enough information to do it. In fact, given the performance benefit achieved by the proposed scheme, it has been recommended within the Extensible MANET Auto-configuration Protocol (EMAP).

In our view, the main contributions of this paper are the analytical evaluation of existing gateway discovery alternatives and a enhanced gateway discovery scheme which achieves a huge reduction in control overhead compared to existing schemes, while offering a very similar packet delivery ratio. In addition, the performance of the protocol has been analyzed through extensive simulation, and the mathematical model has been also validated through simulation.

The remainder of this paper is organized as follows. Section II summarizes the previous solutions which have been proposed for MANET global auto-configuration, and the results of other performance studies of the gateway discovery function. Our proposed adaptive algorithm is described in Sec. III. In Sec. IV, a mathematical model which includes expressions to compute the overhead of the most important gateway discovery approaches is presented, Sec. V simulation-based performance evaluation. Finally, Sec. VI concludes the paper and some future directions to work on.

2. Previous Approaches and Related work

Wakikawa *et al*. propose in [2] a proactive protocol in which the gateways periodically flood the network with control messages called GWADV. While GWADV messages are being forwarded, ad hoc nodes create reverse routes to the gateway. In this way, when a node wants to communicate with nodes in the Internet, it uses the route to the gateway to send the traffic addressed to nodes in the fixed network. The specification does not deal with the situation where multiple gateways are available. A straightforward solution is selecting one of those gateways by a given criterion, e.g. the hop count from the node to the gateway.

The same document [2] also describes an on-demand protocol based on the reactive search of routes to the gateways. In this case, gateways do not send periodic messages. When an ad hoc node needs a gateway to the Internet, it floods a RREQ I message. Every gateway receiving such message replies with a RREP I to the originator in unicast. Reverse routes to the source are set up as the RREQ I is being forwarded, while routes to the gateways are created as the RREP I goes to the source

Hamidian et al. [10] proposed a solution, which provides Internet connectivity to ad hoc networks by modifying the AODV routing protocol. Three methods of gateway discovery for a mobile node to access the Internet are provided: proactive, reactive and hybrid approach. All of them are based only on the number of physical hops to gateway as the metric for the gateway selection.

Bin et al. [11] proposed an adaptive gateway discovery scheme that can dynamically adjust the TTL value of Agent Advertisements (GWADV messages) according to the mobile nodes MANET Internet traffic and their related position from Internet Gateways with which they registered. This protocol provides Internet access to MANET mobile nodes using mobile IP.

The proactive and reactive discovery of gateways is compared in [8] by means of simulation. There, it is found that the reactive approach achieves a better packet delivery ratio at a cost of a higher overhead, especially when the number of data sources present in the MANET increases. However, the proactive approach is shown to poorly scale when there are many gateways.

To get the best of reactive and proactive approaches, hybrid schemes may be used. Ratanchandani *et al*. [4] describe a hybrid solution within the context of Mobile IP. Foreign agents (FA) proactively send advertisements to their closest nodes, while farthest ones operate on demand. To control the scope of the advertised messages the Time To Live (TTL) field of the IP header is set to a fixed value. The problem is that there is not a best TTL for a range of scenarios and network conditions. In [9], an analytical comparison between the reactive, proactive and hybrid approaches is performed.

An interesting solution is described by Jelger *et al*. in [3]. It is a proactive gateway discovery approach which introduces a restricted flooding mechanism based on the *prefix continuity* property. Gateways periodically send out GW INFO advertisements, but each ad hoc node only forwards the messages which it uses to configure its own IP address. This property guarantees that every node shares the same prefix than its next hop to the gateway, so that the MANET gets divided in as many subnets as gateways are present. The next hop to the gateway, i.e., the neighbor which sent the GW INFO message which has been used to create/refresh the default route, is called the upstream neighbor. If this proposal is run along with a reactive routing protocol, a node must check whether it has a bi-directional link with a neighbor before choosing it as its upstream neighbor. To validate this, a simple protocol which involves the sending of three neighbor identifier (NBID) control messages is executed

Finally, Ruiz *et al*. describe in [12] an adaptive algorithm which selects the TTL of the gateway advertisements according to the number of hops between the traffic sources and the gateways. This approach tries to limit the huge overhead which is provoked by the reactive scheme when there are many traffic sources in the network. At the same time, the overhead of the proactive algorithm when the number of gateways increases is also reduced. The same paper performed an analytical study where it is shown how the reactive gateway discovery has a big impact on the overall performance when there are many traffic sources.

3. Description of the QoS based Proxied Adaptive Scheme

In this section we deeply describe the proposed scheme which has been evaluated in this paper. It is based on the *maximal source coverage* algorithm, which was introduced in [12]. Initially, the gateways do not send control advertisements (GC REP) periodically. When a node needs a route to the Internet, it issues a GC REQ message which is flooded throughout the network. The gateways present in the MANET receive the GC REQ and send a GC REP message in uncast to the originator. It contains the subnet prefix which is later on used by the node to auto-configure its global IP address. Reverse routes to the node are created as the GC REQ message is being forwarded and routes to the gateway when the GC REP is sent back. So, the ad hoc node can start sending data traffic to the Internet after configuring its global address.

Data packets addressed to nodes in the Internet pass through a gateway. Thus, it can collect the number of hops from itself to every source. Then, the TTL of the GC REP messages which are periodically flooded is set to the distance to the farthest source. The motivation behind this is that active sources are covered by the proactive sending of control messages, and therefore we can avoid the reactive route discovery when the route to the Internet is lost, which is very expensive in terms of control overhead. The information needed by the gateway (i.e. distance to every source) can be obtained in a number of ways. We explain some options in the EMAP draft [7]:

- In the easiest way, the gateway can impose a default TTL for every source in its area. Then, the number of hops is obtained by subtracting the TTL / Hop Limit field of the IP header from the default TTL.
- Another option is asking the sources to include the default TTL which they use in their GC REQ messages. So, the number of hops can be computed every time a data packet is received.

- Finally, a new Option Header for IPv4/v6 might be included in data packets sent by ad hoc sources. This new header would include the original TTL / Hop Limit which was used when the packet was originated.

It has been reported [12] that the control overhead of the proactive gateway discovery scheme does not scale with the number of gateways. Similarly, the reactive one does not scale as the number of sources increases. Thus, the objective of our proposed scheme is to reduce the amount of control overhead and increase the scalability. We can do that by sending out advertisements to a restricted number of hops. This allows the algorithm to scale well as the number of gateways increases. At the same time, this idea reduces the high number of route discoveries performed by the reactive scheme as the number of sources increase. The reason is that most of them learn the route to the gateway through the limited advertisement, and they don't need to discover it themselves. Thus, we achieve a trade-off between the reactive and proactive solutions and overcome the problem of previous hybrid schemes which statically assigned a fixed scope for the advertisements. Internet gateway periodically broadcasts gateway advertisement proactively throughout MANET domain. Every mobile node creates/updates default routes to an Internet gateway as it receives next gateway advertisement based on interface queue and minimum hop [1]

The overhead consumption is further reduced if we allow intermediate nodes to reply, on behalf of the gateways, when they receive a request. This idea also appears in EMAP, and tries to take advantage of the local information which is acquired by some ad hoc nodes in the network. Since the adaptive algorithm creates a proactive zone and a reactive one, GC REQs do not need to be flooded to the whole network. Intermediate nodes in the border of a proactive zone reply in unicast to the originator with a GC REP, and therefore the overhead is reduced. So, the use of proxies is well suited for hybrid solutions like ours, since many nodes know the existence of at least one gateway.

However, the information provided by the proxy may be not fully fresh compared to the one provided by the gateway. This may cause a bigger latency since a node might start using a global IP address and a route towards Internet that might be no longer available. In that case, it can select a new one when it discovers the problem with current route, but that may increase a little bit the configuration latency. To avoid that, prefix information can be assigned an expiration time.

4. Mathematical Model

In this section we provide an analytical model to compute the gateway discovery overhead which is caused by the reactive, proactive, hybrid, adaptive (with and without proxies) and prefix continuity schemes. We assume that there are N nodes in a square lattice covering a certain area, as in Fig. 1. Each vertex of the lattice represents one and only one node. Some of them, NGW, are gateways placed in the corners of the lattice. Then, we have $N_{adhoc} = N - N_{GW}$ ad hoc nodes. There are S traffic sources which are uniformly distributed in the network, so that every node has the same probability to be a source. Given that we are interested in modeling gateway discovery, we assume that receivers are in the Internet. During the time interval t under consideration, all sources send constant bit rate traffic to the fixed nodes through the gateways. The routing protocol used is the Ad hoc On-demand Distance Vector (AODV) routing [5]. We choose a reactive protocol because, in this paper, our aim is to get low overhead solutions. Therefore, we do not consider proactive routing protocols due to their periodical dissemination of control information. AODV updates a route every time it is used, so active routes do not expire until a link break is detected. that detection may be accomplished either by the use of HELLO messages or by link layer feedback. The latter is assumed (again, because of a lower overhead).

The metric used to choose a route to the gateway is the hop count, since it is common to all solutions and allows for a fair comparison. Therefore, every node selects the nearest gateway to communicate with hosts in the Internet. Under these circumstances, we can assume that there are N_{adhoc} = N - N_{GW} potential nodes which can use a given gateway in their default routes. Whenever a source wants to reactively discover a gateway, it floods the network with a RREQ I message after that, every gateway sends a RREP I reply unicasted to the source. Since the gateways are in the corners of the lattice, it is easy to check that the mean path length is $\sqrt{N} - 1$. Then, the overhead of the reactive gateway discovery for every source is given by Eq. 1.

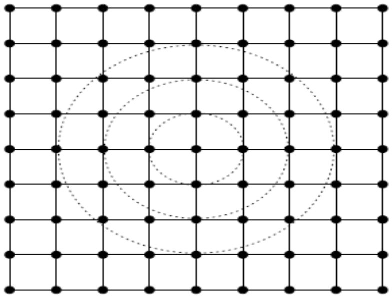


Fig. 1. Square lattice used in the proposed analytical model.

$$\Omega_{r-gw} = N_{adhoc} + N_{GW} . (\sqrt{N} - 1) \quad (1)$$

Link breaks are mainly due to the effects of mobility. When a link between two nodes of an active route breaks, the node that detects it notifies the source by sending a RERR message. This overhead is similar for every approach, and much lower than the gateway discovery function overhead. Moreover, that message is part of the routing protocol rather than the interconnection mechanism itself. Therefore we do not take it into account. The number of link breaks in a given scenario, and number of route discoveries which are caused by those breaks, can be better determined through a simulated analysis. Figure 2 shows the mean number of route discoveries per second which are issued for a range of scenarios with different number of sources and gateways. To get this result, 10 different runs for each case have been performed during

500 seconds. We can see how the number of route discoveries (*rd* (S, N_{GW})) decreases for the cases of 5 and 6 gateways, which is due to the shorter mean path length in those scenarios see Sec. V A to (see this explanation and the remaining simulation parameters) Finally, Eq. 2 gives the overhead of the reactive scheme as the overhead of discovering the gateway reactively multiplied by the number of such route discoveries that need to be done during the time interval t.

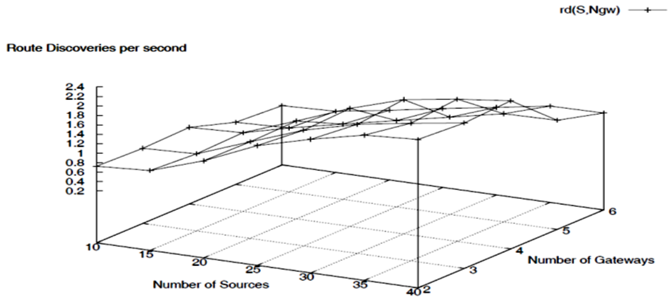


Fig. 2. Mean number of route discoveries per second, *rd* (S, N_{GW}).40 nodes follow the Gauss–Markov mobility pattern at a maximum speed of 20 m/s.

$$\Omega_r = \Omega_{r-gw} \, . \, \mathrm{t.} \left(rd(S, N_{GW})\right) \tag{2}$$

Let us continue our analysis with the overhead of the proactive scheme, where GWADV messages are sent by the gateways to the whole ad hoc network. For each gateway, the associated overhead is of N_{adhoc}+ 1 messages; one forwarding by each of the N_{adhoc} nodes plus the first message which is sent by the gateway itself. Let λ_{adv} be the rate at which GWADV messages are sent out. The overhead of the proactive solution can be obtained as in Eq. 3.

$$\Omega_p = \lambda_{adv} \, . \, t \, . (N_{adhoc} + 1) \, . N_{GW} \tag{3}$$

The hybrid gateway discovery scheme has an overhead which is a combination of the reactive and proactive protocols. As we showed, the mean path length is $\sqrt{N} - 1$. Thus, it makes no sense sending GWADV messages at more than $\sqrt{N} - 1$ hops because other gateways will be covering the area beyond that TTL (assuming gateways are in the corners). The number of nodes which are at an scope of s hops from any gateway is approximated2 by Eq. 4, with $s \in \left[0, \sqrt{N} - 1\right]$.

$$N_r^{GW}(s) \simeq \sum_{j=1}^{s}(j+1) = \frac{s(s+3)}{2} \tag{4}$$

For a given scope s configured at each gateway, the probability for a node to receive a GWADV message from any of the gateways can be computed as shown in Eq. 5. It is an approximated expression, since not all the gateways necessarily cover the same number of ad hoc nodes.

$$P_{c(s)} \simeq \frac{N_r^{GW}(s) \, . N_{GW}}{N_{adhoc}} \tag{5}$$

If we denote N_c as the number of sources being covered by any gateway when using a scope of s hops, then N_c is a random variable obeying a binomial distribution $B \sim (S, Pc\,(s))$. Thus, the mean number of sources being covered when gateways use a scope of s hops can be computed as $E\,[N_c] = S \cdot P_{c(s)}$). So, the overall overhead of the hybrid approach consists of the proactive sending of GWADV messages up to s hops, plus the reactive discovery of a gateway by those sources not covered by the GWADV messages (Eq. 6).

$$\Omega_h^s = \lambda_{adv} \, . \, t \, . (N_r^{GW}(s) + 1) \, . N_{GW} + \\ \Omega_{r-gw} \, . \, \mathrm{t.} \left(rd(S, N_{GW})\right) . \left(1 - P_{c(s)}\right) \tag{6}$$

The adaptive solution based on maximal source coverage is similar to the hybrid approach, but in this case the TTL s is set to the distance to the farthest source. Let us see a simple example to describe the process of getting the most likely TTL which is used by the algorithm. Let us concentrate on a corner of the lattice, with N_{GW} = 1, N_{adhoc} = 5 and S = 2. Obviously, there are two nodes one hop away from the gateway, and three nodes at a distance of two hops. Starting with the first source, it can be placed at a distance of 1 hop with a probability p (1) = 2 /5, or at 2 hops with probability p (2) = 3/ 5.

Assuming that it was placed 1 hop away from the gateway, now we have $p(1|1)$ = 1/ 4 and $p(2|1)$ = 3 /4 the probabilities for the second source to be at a distance of 1 or 2 hops, respectively given that the first source is at distance 1 hop. On the other hand, if the first source was placed at a distance of 2 hops, the probabilities for the second source are p (1|2) = 2/ 4 and p (2|2) = 2/ 4. Therefore, with our maximal source adaptive algorithm in which the selected TTL is set to the number of hops of the furthest away source, the probability to set the TTL of the advertisements to 1 is given by $p(1) \cdot p(1|1)$ = 0.1. The probability of setting it to 2 is $p(1) \cdot p(2|1) + p(2) \cdot p(1|2) + p(1) \cdot p(2|2)$ = 0.9. Therefore, the mean TTL is given by 1·0.1+2·0.9 = 1.9.

Generalizing the expression, for each gateway the probability of selecting a particular TTL is given in Eq. 7, being $p(k|i, j, \ldots. n\text{-}1 \ldots)$ the conditional probability of having the n^{th}source at a distance of k hops, given that the 1^{st} source is at i hops, the 2^{nd} at j hops, etc. In our model, $p(k|i, j, n.{-}1\ldots)$ can be computed as $\frac{k+1-c(i,j,\ldots)}{N_{adhoc}-n(i,j,\ldots)}$, being $c(i, j, \ldots)$ the number of sources which have been already placed at a distance of k hops; $n(i, j, \ldots)$ the total number of sources which have been already placed; and k+1 is the total number of nodes at a distance of k hops from the gateway. I.e., the numerator represents the number of nodes at a distance of k hops which have not been selected as sources yet, and the denominator is the total number of nodes which have not been selected as sources yet. The expression in Eq. 7 is just a generalization of the process followed in the previous example.

$$\mathrm{P}(TTL = s) = \sum_{i=1}^{s} \sum_{j=1}^{s} \underset{\dots}{S} \sum_{k=1}^{s} p(i).\ p(j \backslash i) \underset{\dots}{S}\ \mathrm{p}(k \backslash i, j, \dots.),$$

$$\mathrm{I} = \mathrm{s} \backslash \mathrm{j} = \mathrm{s} \backslash \underset{\dots\dots\dots}{S} \backslash \mathrm{k} = \mathrm{s} \qquad (7)$$

The average TTL which is used in our adaptive scheme is given by Eq. 8. Applying this result to the expression in Eq. 6, we get the equation of the overhead caused by the adaptive protocol (see Eq. 9).

$$s_{avg} = \sum_{i=1}^{\sqrt{N}-1} \mathrm{i} \,.\, \mathrm{P}\ (TTL = i) \qquad (8)$$

$$\Omega_a = \Omega_h^{s_{avg}} = \lambda_{adv} \,.\, t \,.\!\left(N_r^{GW}\ (s_{avg}) + 1\right).N_{GW} + \Omega_{r-gw} \,.\, \mathrm{t}.\left(rd(S, N_{GW})\right).\left(1 - P_{c(s_{avg})}\right) \qquad (9)$$

If we add the proxy support to the latter solution, the needed overhead to discover routes to the gateways must be changed. GC REQ messages are only sent by nodes outside a proactive zone. They are flooded to the whole reactive zone, and therefore there are as much forwarding as nodes in that zone. So, the overhead is given by the number of nodes which are placed outside the proactive zone, $N_{pz\_out} = N_{adhoc} - N_{GW} \cdot N_r^{GW}\ (s_{avg})$. The GC REP is sent by the nodes placed just in the border of a proactive zone. The number of such nodes can be computed as $N_{pz\_border} = N_{GW} \cdot N_r^{GW}\ (s_{avg}) - N_r^{GW}\ .(s_{avg} - 1) = N_{GW}.\ (s_{avg} + 1)$. Combining expressions, the expected overhead per each source which does not receive periodic GC REP messages is given by Eq. 10, and the total overhead of our new adaptive scheme is in Eq. 11

$$\Omega_{p\_gw} = N_{pz\_out} + N_{pz\_border} = N_{adhoc} + N_{GW}\ .\left[(s_{avg}) + 1 - N_r^{GW}\ (s_{avg})\right] \qquad (10)$$

$$\Omega_{ap} = \lambda_{adv} \,.\, t \,.\!\left(N_r^{GW}\ (s_{avg}) + 1\right).N_{GW} + \Omega_{p-gw} \,.\, \mathrm{t}.\left(rd(S, N_{GW})\right).\left(1 - P_{c(s_{avg})}\right) \qquad (11)$$

Finally, let us get an expression for the overhead caused by the prefix continuity solution. There is a request/reply process when a node requires global connectivity, and therefore the overhead is the same as in the reactive approach. But, in addition, there is a proactive restricted flooding at a rate of λ_{adv} messages. No matter the number of gateways present in the network, since the whole MANET is divided in as many sub networks as gateways exist; and GW INFO messages sent out by a given gateway are only forwarded by the nodes inside its subnet work. So, the approach based on prefix continuity always forwards N messages when gateways issue a GW INFO. To validate that every ad hoc node has a bi-directional link to its selected upstream neighbor, a simple protocol which involves the sending of 3 NBID messages is executed. The problem here is to determine how many times a node is going to change its upstream neighbor. Let us assume that this will happen when the link to the upstream neighbor gets lost (mainly due to mobility) and a new one is selected.

We denote by L_{dur} the link duration time (i.e., the time between link breaks). Then, L_{dur} obeys an exponential random distribution with parameter λ_{dur} Let us assume that every link follows the same distribution. Let N_{break} be a random variable representing the number of link breaks during an interval of t units of time. Then, N_{break} follows a Poisson distribution with an arrival rate equal to λ_{dur} , so that P $[N_{break} = k] = \frac{e^{-\lambda_{dur}} {\lambda_{dur}}^{k}}{k!}$. So, the mean number of breaks which a link experiences is given by $E\ [N_{break}] = \lambda_{dur} t$. Putting all together, there is a resulting overhead expressed in Eq. 12.

$$\Omega_j = \lambda_{adv} \,.\, t \,.\mathrm{N} + 3.\ N_{adhoc} \,.\, \lambda_{dur} \,.\, \mathrm{t} + \Omega_{r-gw} \,.\, \mathrm{t}.\left(rd(S, N_{GW})\right) \qquad (12)$$

The model predicts a good scalability of the QoS based analysis of Proxied Adaptive gateway discovery scheme both with respect to the number of sources and gateways. They are expected to provoke a bigger overhead than the proactive approach when there are few gateways, but they get the best values for the remaining cases. Furthermore, the model predicts that the proxied scheme will improve the overhead thanks to the limitation of the flooded requests.

5. Simulation Based Performance Equation

We have implemented the proactive and reactive schemes, the approach based on prefix continuity, and the maximal source coverage adaptive scheme with and without the proxying support.

5.1 Simulation Environment

In this section, we apply the above proposed gateway discovery algorithm, which is implemented using the network simulator ns-2.28 [13] and compare it with A. Hamidian [10] Proactive discovery solution in the same simulation environment. In Ad Hoc network domain, we use AODV routing protocol. The simulations were conducted on an Intel Pentium IV Processor at 3.0 GHz, 512 MB of RAM running Fedora Core 2 Linux.

As we assumed AODV as the routing protocol in our analytical study, the same protocol is used in the simulation. Routes are updated every time a data packet is successfully sent, and get invalidated when a link break is detected (in accordance with the specification [5]). Link breaks are detected using link layer feedback. We have set up a scenario consisting of 40 mobile Nodes using 802.11b at 2 Mb/s with a radio range of 250 m. These nodes are placed in a rectangular area of 1500x300 m^2. We have varied the number of gateways from 2 to 6, being located at the corners of the simulation area. In the case of 2 gateways, they are at opposite corners. The 5th and 6th gateways are located at the center of the X axis, at the top and the bottom respectively. In the simulated scenarios, the inclusion of the 5th gateway reduces the mean path length by a factor of 1.48 with respect to the scenarios with 6 gateways. Sources send UDP traffic at a constant bit rate of 10 Kbps, with 512 bytes per packet.

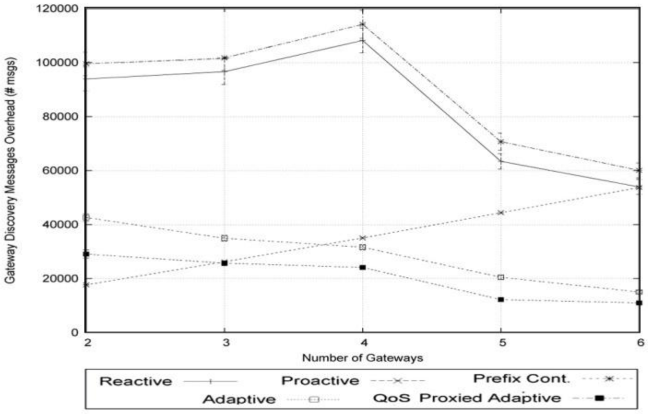
We have simulated 20, 25, 30, 35 and 40 sources. All data packets are sent from nodes in the MANET to nodes in the fixed network. Every source begins transmitting data within the first 50 seconds of the simulation, at a randomly chosen time. The mobility patterns have been generated by the Bonn Motion tool. The Gauss–Markov mobility model has been used, with a maximum speed of 20 m/s. In this model, a node picks a random speed and direction and starts moving. At regular intervals of time, the node selects another speed and direction and repeats the process. But these new values are based on the previous ones, so there are no strong changes of speed and direction. All simulations have been run during 1000 seconds. The first 100 seconds have been cut off, to make sure that the network has reached the steady state. To convey significant statistical information, 20 different runs have been performed per each scenario.

5.2 Simulation *Results*

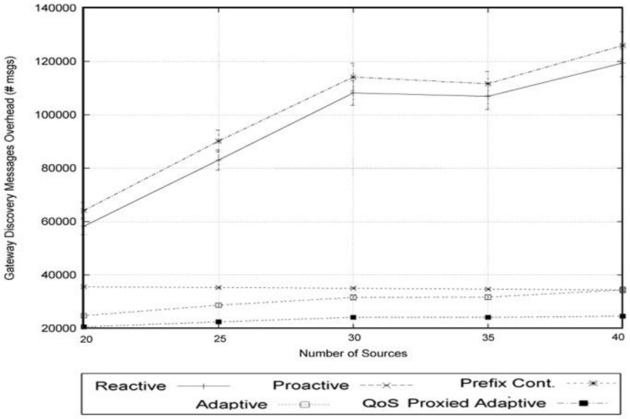
To assess the effectiveness of the proposed gateway discovery mechanism, we used the following performance metrics:

Gateway discovery overhead: The sum of all sent or forwarded auto-configuration messages.
Packet delivery ratio: The relation between the total numbers of data packets successfully received over the total number of data packets which have been sent.
Normalized control overhead: The relation between the total numbers of data packets successfully received plus the whole control overhead, over the total number of data packets successfully received. Here the control overhead considers every forwarded message related to the routing and auto configuration protocol. This metric measures the efficiency of the protocol, i.e., its internal effectiveness. An ideal protocol would have a normalized control overhead of 1, meaning that it does not need any control message to deliver data packets to their destination.

Figure 4 shows the gateway discovery overhead with respect to the number of gateways and sources. We can see that the proactive approach increments its overhead as the number of gateways increases, as it was predicted by the model (Fig. 4(a)). The reactive and prefix continuity solutions slightly worsen their performance as more gateways are being added, but they greatly reduce the overhead for the case of 5 and 6 gateways. This happens because the mean path length from every source to a gateway is shorter and the probability of experiencing a link break in any route is lower Adaptive scheme gets the best results. When the maximal source coverage algorithm is executed without proxying support, it obtains a much lower overhead than the reactive approach in every case, and is better than the proactive solution when there are some few gateways in the network. This occurs thanks to the scoped flooding of the advertisements, which is dynamically adapted depending on the load of the network. When QoS proxies adaptive are used, further improvement is experienced in the overhead consumption, since they limit the propagation of the flooded requests.



(a) 6 gateways



(b) 40 sources

Fig. 4. Gateway discovery overhead versus the number of gateways and Sources.

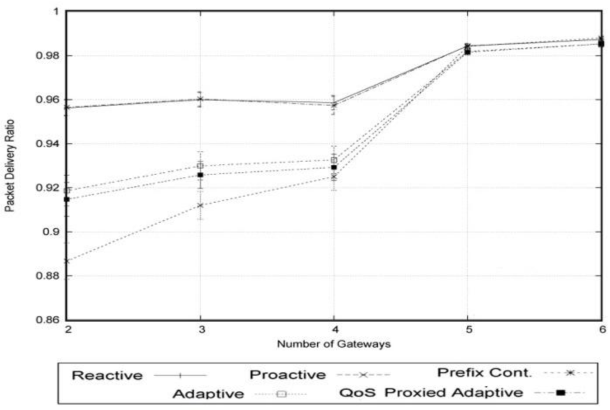
Regarding the scalability with respect to the number of sources, figure 4(b) fact that the reactive discovery of gateways incurs in a huge overhead when the number of sources increases. The proactive approach maintains its overhead at a constant level because gateways send their advertisements regardless the number of sources in the network. Our adaptive mechanisms are better than the proactive one when there are some few gateways. The good point is that the adaptive scheme scales well with respect to the number of sources, since it slightly increments its overhead as more sources are added to the network. This is especially noticeable when QoS proxies adaptive are used, since the more sources are in the network, the more likelihood of having a proxy which knows a route to the Internet.

The improvement of the adaptive scheme over the reactive, with the network conditions of Fig. 4(a), ranges from a factor of 2.35 to 3.46. When compared to the proactive solution, the maximal source coverage loses 2.4 times of performance in the case of 2 gateways, but is able to reduce the overhead to a factor of 3.57 for the 6 gateways scenario.

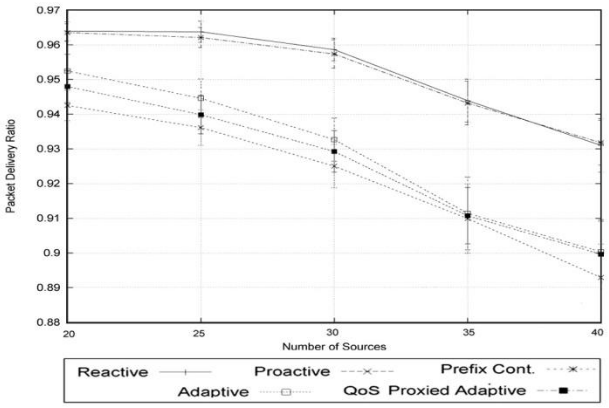
In addition, you can see in Fig. 4(b) how it performs better than the proactive approach regardless the number of sources, for the case of 6 gateways. The QoS proxied adaptive scheme is the one with the lowest control overhead. When compared to the basic maximal source coverage algorithm, the experienced improvement in overhead reduction ranges from a coefficient of 1.36 to 1.46. The great improvement in terms of overhead reduction which is achieved by the proposed QoS proxied adaptive scheme comes at the cost of a light reduction in the packet delivery ratio (Fig 5).

The proactive scheme drops more data packets because, when the route to the Internet is lost; nodes must enqueue data packets and wait for the next advertisement. So, queues tend to full up and data packets are dropped. The same explanation applies to the proactive zone of our adaptive schemes. However, they achieve a better packet delivery ratio because the nodes in the reactive zone operate reactively In addition; the collision probability is lower since they do not flood the periodic advertisements to the whole network.

The reactive and prefix continuity solutions present the best delivery ratio because routes are searched as soon as they are needed, and the data buffers do not get filled. In general, the delivery ratio improves as the number of gateways gets higher, since the mean path length to the gateways is shorter and therefore the routes are less prone to suffer a link break. On the other hand, the bigger the number of sources, the worse performance because there is a bigger link layer contention and collision probability. The packet delivery ratio of the reactive algorithm is from 0.2% to 3.8% better than the adaptive one, which outperforms the proactive scheme by up to a 3.2%.

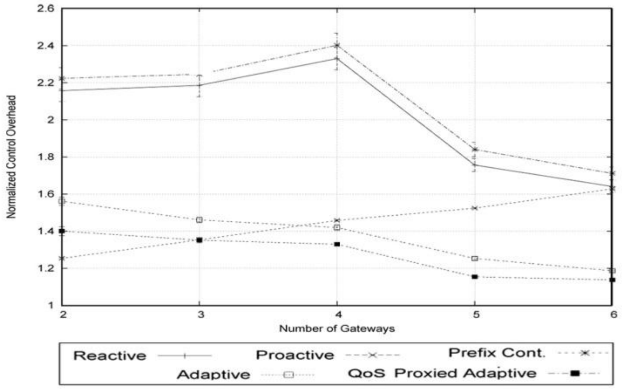


(a) 6 gateways

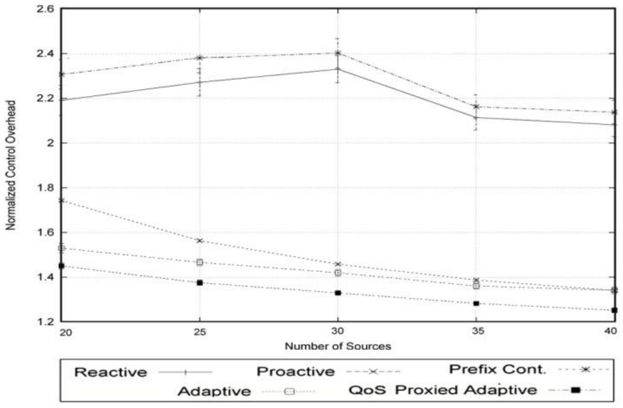


(b) 40 sources

Fig. 5. Packet delivery ratio versus the number of gateways and sources.



(a) 6 gateways



(b) 40 sources

Fig. 6. *Normalized control overhead* versus the number of gateways and Sources.

When proxies are enabled in the adaptive solution, a reduction of about a 0.4% is obtained. As we can see, differences across approaches are very low. Taking into consideration the overhead and the delivery ratio, adaptive schemes offer the best trade-off. Figure 6 shows the normalized control overhead, where you can see how the reactive schemes perform the worst when few gateways are present. The proactive and adaptive are similar, although the latter scale with respect to the number of gateways and the former does not. Finally, the use of QoS proxies adaptive further improves the overall performance achieved by the adaptive scheme based on maximal source coverage.

6. Conclusions

In this paper, the QoS performance of the most important mechanisms for gateway discovery in hybrid ad hoc networks has been investigated. A brief review of the previous solutions has been presented, and we have developed a new adaptive scheme which exploits the local information acquired by intermediate nodes to limit the flooding of the requests. This approach, where proxies are allowed to reply instead of the gateways, takes advantage of our hybrid scheme which dynamically sets the scope of the gateway advertisements.

The results show how the maximal source coverage algorithm outperforms the remaining approaches for a wide range of scenarios and network conditions. When proxies are enabled, the overhead is reduced even more. In addition, adaptive schemes offer a good packet delivery ratio, although it is not as high as the one provided by the reactive and prefix continuity solutions. However, it may be worthwhile losing approximately a 3.8% of packet delivery ratio if the protocol reduces the overhead consumption up to 3.46 times (comparison between the reactive and the adaptive with proxying scheme). In fact, QoS based analysis of Proxied Adaptive gateway discovery scheme have the best effectiveness in terms of delivering data packets at a low cost of overhead. This advantage may help to extend the lifetime of a network based on power-limited devices, since the use of the network interfaces is very power-consuming. In future work we plan to adapt other different protocol parameters, like the interval between the gateway advertisements, in base of other network conditions like the load aware and mobility of the nodes.

References

[1] *Rakesh Kumar1, Manoj Misra1 and Anil K. Sarje1 Department of Electronics and Computer Engineering, Indian Institute of Technology, Roorkree, India, A Proactive Load-Aware Gateway Discovery in Ad Hoc Networks for Internet Connectivity," International Journal of Computer Networks & Communications (IJCNC) Vol.2, No.5, September 2010*

[2] *R. Wakikawa, J. Malinen, C. Perkins, A. Nilsson, and A. Tuominen, "Global Connectivity for IPv6 Mobile Ad Hoc Networks" (Work in progress), draft-wakikawa-manet-globalv6-04, IETF Internet-Draft, July 2005.*

[3] *C. Jelger, T. Noel, and A. Frey, "Gateway and Address Auto configuration for IPv6 Ad Hoc Networks" (work in progress), Draft-jelger-manet-gateway-autoconf-v6-02, IETF Internet-Draft, April 2004.*

[4] *P. Ratanchandani and R. Kravets, "A Hybrid Approach to Internet Connectivity for Mobile Ad hoc Networks", in Proc. of the IEEE WCNC 2003, Vol. 3, pp. 1522–1527. New Orleans, USA, March 2003.*

[5] *C. Perkins, E. Belding-Royer, and S. Das, "Ad hoc On Demand Distance Vector (AODV) Routing", IETF RFC 3561, July 2003.*

[6] *T. Clausen, and S. Singh, "Ad-Hoc Network Auto configuration (autoconf)" Charter, http://www.ietf.org/html.charters/autoconf-charter.html*

[7] *F. Ros, and P. Ruiz, "Extensible MANET Auto-configuration Protocol (EMAP)" (work in progress), draft-ros-autoconf-emap-02, IETF Internet-Draft, March 2006.*

[8] *M. Ghassemian, P. Hofmann, C. Prehofer, V. Friderikos, and H. Aghvami, "Performance Analysis of Internet Gateway Discovery Protocols in Ad hoc Networks", in Proc. of IEEE Wireless Communications and Networking Conference, March 2004.*

[9] *M. Ghassemian, V. Friderikos, and H. Aghvami, "On the Scalability of Internet Gateway Discovery Algorithms for Ad Hoc Networks", in Proc. of International Workshop on Wireless Adhoc Networks, May 2005.*

[10] *A. Hamidian, U. Korner, and A. Nilsson, "A Study of Internet Connectivity for Mobile Ad Hoc Networks in NS2", Department of Communication Systems, Lund Institute of Technology, Lund University, January 2003.*

[11] *S. Bin, S. Bingxin, L. Bo, H. Zhonggong, and Z. Li, "Adaptive gateway Discovery Scheme for Connecting Mobile Ad Hoc Networks to the Internet," Proceedings of International Conference on Wireless Communications, Networking and Mobile Computing, vol. 2, pp. 795-799, 2005*

[12] *Francisco J. Ros, Pedro M. Ruiz "Low Overhead and Scalable Proxied Adaptive Gateway Discovery for Mobile Ad Hoc Networks Dept. of Information and Communications Engineering University of Murcia", Mobile Adhoc and Sensor Systems (MASS), 2008 IEEE InternationalConferenceon IssueDate:Oct.2008 On page(s):226 - 235.*

[13] *NS 2 Home page: http://www.isi.edu/nsnam/ns/ index.html*

First Author K.Palani is an Assistant Professor (Senior Grade) in computer science and engineering department in Tamilnadu College of Engineering at Coimbatore, TamilNadu, India. He holds B.E, M.E degree in computer science and engineering from Madras University, Anna University Chennai respectively in 1999 and 2006. He is currently pursuing his research work for PhD degree in computer science and engineering. He has more than 12 years of experience in teaching and current research interests in Mobile ad hoc networks, wireless internet, and wireless security and ad hoc wireless Routing protocols.

Second Author Dr.P.Ramamoorthy is a former Principal and professor & head of the Department of Electronic Communication Engineering, Government College of Technology in Coimbatore and He has currently working Dean (Academic), Sri Shakthi Institute of Engineering and Technology, Coimbatore, Tamilnadu, India. He has a B.E Degree in electronics communication engineering from University of Madras in 1976. He secured the M.E in electrical engineering from PSG Technology Coimbatore in 1978 and the PhD degree from Anna University Chennai in 2009. He has published nearly 42 papers in international journals, seminars and symposia. His areas of interest are wireless sensor networks, neural networks, wireless networks, MANET and genetic algorithms.