

# A Survey of Adaptive Gateway Discovery Mechanisms in Heterogeneous Networks

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**Abstract**— The communication range of devices within a mobile ad hoc network is inherently restricted. One way of enhancing the communication range of a mobile ad hoc network, is to interconnect it to a wired network like the internet, thus forming a heterogeneous wired cum wireless network. This interconnection also enables mobile nodes to access internet services, and is achieved through gateways. Mobile nodes in the ad hoc network need to discover and register with a gateway in order to obtain Internet connectivity. Gateway discovery mechanisms called proactive, reactive and hybrid exist to enable mobile nodes to register with internet gateways. In the recent times, few optimizations have been proposed to the existing gateway discovery mechanisms in order to make gateway discovery by mobile nodes efficient. In this paper, we present a detailed survey of the state of the art in gateway discovery and selection mechanisms.

**Index Terms** — Mobile Ad Hoc Network, Heterogeneous Networks, Gateway Discovery Mechanisms, Adaptive Gateway Discovery

## I. INTRODUCTION

Internet has revolutionized the way people communicate. The advent of mobile devices has greatly eased this communication process further. While the Internet facilitates communication without restriction to geographical area, thereby bringing down physical barriers to communication, a mobile ad hoc network (MANET) [1], which is an impromptu network made up of mobile devices, facilitates people to communicate without the need for pre existing infrastructure. Various routing protocols have been proposed to perform routing in MANETs [2]. The performance comparison of some of the major ad hoc network routing protocols can be found in [3]. The Internet and mobile ad hoc network offer a complimentary set of communication features. The Internet is based on a worldwide infrastructure, whereas

the infrastructure-less mobile ad hoc network offers the benefit of communication on the move. By itself, a mobile ad hoc network is of limited use, because, communication can take place only among the devices which are part of the network. For this reason, to let mobile devices within an ad hoc network to communicate with any other device anywhere in the world, the mobile ad hoc network is connected to the Internet, resulting in a heterogeneous internetworking architecture. Several strategies exist which define various architectures for interconnecting mobile ad hoc networks to the Internet. These strategies use Mobile IP [4], which provides single hop wireless Internet connectivity, and extend its functionality to multiple hops. A general architecture of an Internet integrated MANET is shown in fig 1.

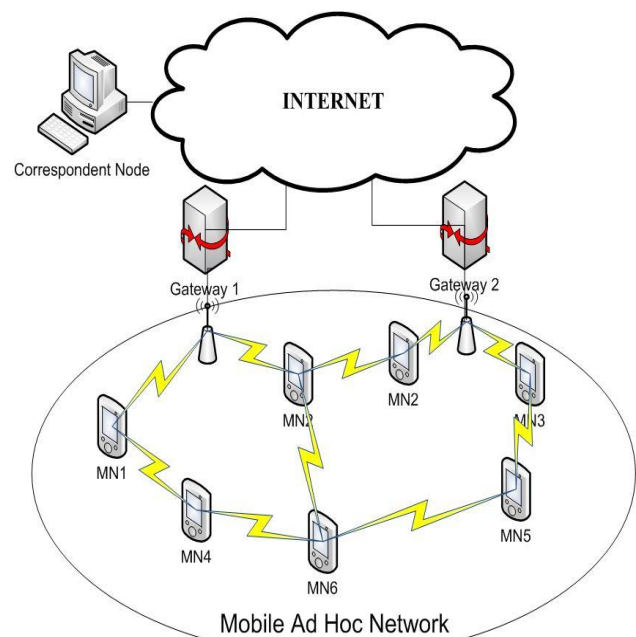


Figure 1. Architecture of an Internet integrated MANET

For a mobile node to use a gateway, it has to first discover and then register with the gateway. Different gateway discovery and registration mechanisms are described in [5].

One of the important optimizing issues in the interconnection of mobile ad hoc networks with wired Internet is the load balancing of gateways [6]. Other issues are multi homing [7] and hand offs [8]. A framework for the performance analysis of integration strategies is given in [9].

Gateway registration can be achieved in one of three ways: proactive, reactive or hybrid. An implementation and performance analysis of these three approaches is provided in [10] and [11]. Each of these schemes has its own strengths and drawbacks. The hybrid approach of gateway discovery has attracted the interest of researchers due to its flexibility. Few variations have been proposed to this approach, which are termed adaptive gateway discovery mechanisms.

In this paper, we first discuss the issues in traditional gateway discovery approaches like proactive, reactive and hybrid and then review the adaptive gateway discovery approaches present in the literature. We present the strengths and drawbacks of each of the approaches. Finally, we also discuss the future directions of research in the area of adaptive gateway discovery.

The rest of the paper is structured as follows: section II presents related survey works in the area of heterogeneous networks. Section III contains a brief overview of the three types of traditional gateway discovery mechanisms. Section IV presents the review of adaptive gateway discovery mechanisms. A comparison of the strategies is presented in Section V. Finally, section VI concludes the paper.

## II. RELATED WORK

A few papers on the survey of strategies for the integration of wired and wireless networks are summarized below.

The work by Abduljalil et al [28] surveys the work integration of mobile IP with mobile ad hoc networks. In [29], [30] and [31], various strategies for integrating mobile ad hoc networks with the internet and the issues to be addressed are discussed. The issue of gateway load balancing in internet integrated MANET has also been addressed extensively in the literature and is surveyed in [6]. An analytical model for the analysis of integration strategies is presented in [32].

## III. GATEWAY DISCOVERY IN HETEROGENEOUS NETWORKS

As mentioned in section I, mobile nodes need to discover and then register with gateways in order to obtain Internet connectivity. There are three different gateway discovery mechanisms defined in the literature [11]. We present a brief overview of each of these:

### A. Proactive Gateway Discovery:

In the proactive gateway discovery approach, the gateway periodically transmits gateway advertisement messages (GW\_ADV) containing relevant information using which a mobile node can register with the gateway. The GW\_ADV message contains a time to live (TTL) field which determines for how many hops this message is forwarded. At each hop, TTL is decreased. Finally, when TTL reaches 0, the message is not further forwarded. Mobile nodes outside the range of TTL will not be able to use this gateway to obtain internet connectivity.

### B. Reactive Gateway Discovery

In the reactive gateway discovery approach, the gateway does not send GW\_ADV messages. Whenever a mobile node desires Internet connectivity, it broadcasts a gateway solicitation message (GW\_SOL). When the GW\_SOL message reaches a gateway, it sends a GW\_ADV message to the mobile node, which then registers with the gateway.

### C. Hybrid Gateway Discovery

In the hybrid approach, mobile nodes in a part of the mobile ad hoc network, defined by the TTL value use the proactive approach for gateway discovery and the rest of the nodes outside the TTL range use the reactive approach.

For example, in fig 2, TTL is set to 2. When gateway 1 transmits a GW\_ADV message, only mobile node 1 (MN 1) receives this message since it is within the transmission range of the gateway. This is default Mobile IP [4] functionality. On receiving the GW\_ADV message, it decrements the TTL value from 2 to 1 and forwards it. Mobile node MN 4 receives the forwarded GW\_ADV message. This mobile node again decrements the TTL value, which now becomes 0. Therefore, the GW\_ADV is not further forwarded. Now, mobile node MN 6 which is outside the proactive zone will use the reactive approach of gateway discovery if it desires Internet connectivity. It is said to be in the reactive zone. The same approach is followed by the nodes registered with gateway 2.

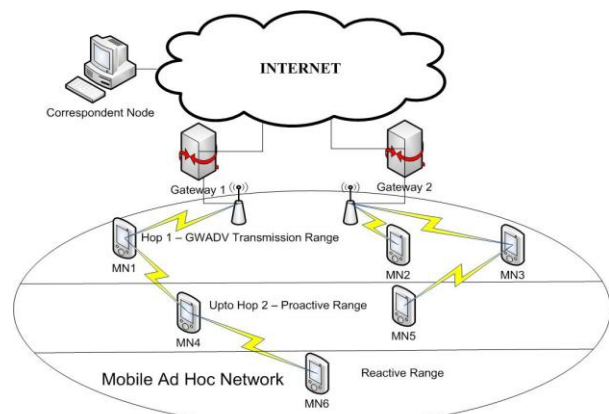


Figure 2. Gateway Discovery Mechanisms in Heterogeneous Networks.

#### D. Issues in Hybrid Gateway Discovery

The primary challenge in the design of Hybrid Gateway Discovery is how to determine an optimal proactive area. If the proactive area is large (i.e. a large TTL value) more overhead is incurred in maintaining routes in a wider area. On the other hand, if proactive area is small, then less maintenance overhead is incurred but more delay in Gateway Discovery is experienced. In traditional Hybrid Gateway Discovery approach, the TTL is set statically and never changed. This leads to a rigid implementation of the proactive area. Existing integration strategies which use the hybrid approach set the proactive area statically and do not dynamically adjust it, which may not turn out to be a proper range anymore for changing network conditions.

A second issue is determining the periodicity of the GW\_ADV messages. The periodicity of the GW\_ADV message determines the number of GW\_ADV messages that will be flooded into the MANET per second. A high periodicity leads to more control messages in a sparse MANET whereas low periodicity may result in starvation of Internet connectivity to mobile nodes in a dense MANET.

#### IV. ADAPTIVE GATEWAY DISCOVERY MECHANISMS IN HETEROGENEOUS NETWORKS

From the discussion in section III it can be concluded that: To offset changing ad hoc network conditions like node density, transmission quality etc; a static TTL value cannot be used. A modified Hybrid Gateway Discovery mechanism which dynamically adjusts value of TTL and periodicity of GW\_ADV messages depending on the MANET characteristics in order to achieve a good trade-off between performance and network overhead is called an Adaptive Gateway Discovery Mechanism. Several novel strategies have been proposed recently which implement adaptive gateway discovery mechanisms in different ways. The purpose of this survey is to review these adaptive gateway discovery mechanisms.

We follow the following approach in reviewing each of the strategies: first we present the salient features of the adaptive gateway discovery mechanism. Then we present the two important features of that adaptive gateway discovery mechanism, viz. TTL value calculation method and GW\_ADV periodicity calculation method.

##### Strategy 1:

This proposal [12] focuses on dynamic adjustment of the TTL value. An active source is the mobile node which is registered with this gateway and is sending data packets to a correspondent node via this gateway. In the proposed approach, each gateway keeps track of the number of hops at which each of its active sources is located. This is easy for the gateway to do since all data packets of

mobile nodes registered with a particular gateway have to pass through that gateway.

To determine the TTL value if the next GW\_ADV message, the maximal source coverage algorithm is used. The maximal source coverage algorithm states that the TTL value of the next GW\_ADV message of a gateway will be equal to the maximum number of hops among all its active sources.

In fig 3, MN 5 and MN 6 are active nodes. The current value of TTL is 2. If a static approach of setting the TTL value is used, then TTL will continue to be 2. On the other hand, in the maximal source coverage approach, the gateway keeps track of the number of hops the active sources are away from it. MN 5 is 2 hops away and MN 6 is 3 hops away. For the next GW\_ADV message, the TTL value is set to 3, which is the maximum distance any active source is from the gateway. In this way, the proactive zone is dynamically adjusted and MN 6 also comes within the proactive zone.

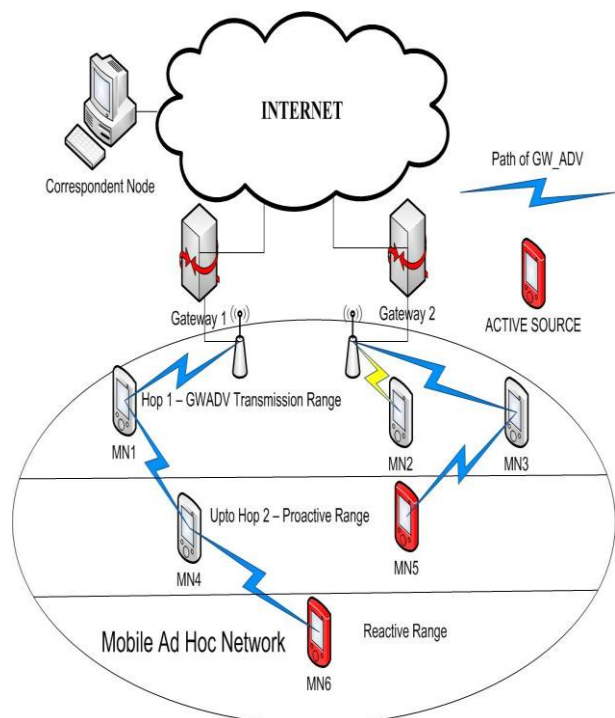


Figure 3. Maximal Source Coverage Adaptive Gateway Discovery

This is one of the first adaptive gateway discovery mechanisms to be proposed. While this mechanism focuses on dynamic adjustment of TTL value, it does not address the issue of periodicity of the GW\_ADV messages. The authors have also suggested various other metrics apart from maximal source coverage, like average source coverage and minimal source coverage.

##### Strategy 2:

This strategy [13] is based on the dynamic adjustment of the TTL value of GW\_ADV messages.

An algorithm called maximal benefit coverage is introduced wherein gateways set the TTL value of their

GW\_ADV messages which gives maximal benefit. In order to compute maximal benefit, a ratio is used whose numerator represents the cost of flooding the whole ad hoc network with GW\_ADV messages and the denominator denotes the cost of providing internet connectivity without sending a single GW\_ADV message. This ratio is used to determine the most appropriate TTL value for the GW\_ADV message.

The periodicity of the GW\_ADV message is not adjusted dynamically.

#### Strategy 3:

A very simple approach is followed in [14]. When an Internet gateway boots up, it starts sending GW\_ADV messages in a predefined proactive zone. When the MANET has stabilized, and mobile nodes register with the gateway, it periodically checks the distribution of mobile nodes in the MANET according to simple criteria and adjusts the value of the TTL accordingly. If the average number of hops to all the mobile nodes which desire Internet connectivity is less than 3, the gateway stops sending the periodic GW\_ADV message and instead relies on GW\_SOL messages from the mobile nodes to provide Internet connectivity. If the average number of hops is greater than 3 but less than 8, the TTL value of the GW\_ADV message is set to the average number of hops. Finally, if the average number of hops is greater than 8, the TTL value is set to the average number of hops and the regularity of GW\_ADV messages is also increased.

#### Strategy 4:

This strategy [15] dynamically adjusts the TTL value of the GW\_ADV messages as well as the advertisement interval according to the topology change and the movement of nodes.

Consider the case where only one gateway exists and is placed in the center of the MANET and mobile nodes which desire Internet connectivity are uniformly distributed. The ratio of the number of nodes whose distance is less than or equal to  $i$  hops from the gateway and the number of nodes whose distance is exactly  $i$  hops from the gateway is estimated and denoted as  $P_s(i)$ .

Similarly, when there is more than one gateway with a similar uniform distribution, the ratio of the number of nodes whose distance is less than or equal to  $i$  hops from the gateway and the number of nodes whose distance is exactly  $i$  hops from the gateway is estimated and denoted as  $P_m(i)$ . The average of  $P_s(i)$  and  $P_m(i)$  is used as a threshold value to determine the TTL.

The adjustment of the advertisement periodicity or advertisement interval is based on movement degree, which is defined as the ratio of number of nodes sending GW\_SOL messages to the gateway to the number of nodes registered with the gateway during the last GW\_ADV cycle. The movement degree is denoted by MD. If the computed MD value is greater than the threshold  $\beta$  then the gateway should decrease the advertisement interval, otherwise, the interval should be increased.

#### Strategy 5:

Generally, in the MANET routing protocols, bi-directional links are assumed. It is more likely that links will be unidirectional in wireless networks owing to the inherent challenges of the wireless medium. This strategy [16] removes unidirectional links from route computations and redundant broadcast of control packets is inhibited.

For this purpose, a concept of symmetric and asymmetric neighbor sets is used. To dynamically adjust the TTL value of the GW\_ADV message, every gateway uses the following statistics: total\_nbr\_src- The total number of source nodes, avg\_hops\_most\_src- the average distance between the gateway and most source nodes, avg\_hops\_all\_src- the average distance between the gateway and all source nodes, largest\_hop\_src- the farthest distance to the gateway of all source nodes.

Every gateway adjusts the TTL of the GW\_ADV message according to the following algorithm: If the total\_nbr\_src is less than MIN\_NBR\_SRC or avg\_hops\_most\_src is less than MIN\_HOPS, then the TTL is set to 0. On the other hand, if total\_nbr\_src is greater than MAX\_NBR\_SRC or avg\_hops\_most\_src is greater than MAX\_HOPS, then, the TTL is set to the largest\_hop\_src, otherwise, TTL is set to the avg\_hops\_all\_src. Here, MIN\_NBR\_SRC, MIN\_HOPS, MAX\_NBR\_SRC and MAX\_HOPS are threshold values which denote minimum neighbor of sources, minimum hops, maximum neighbor of sources and maximum hops.

#### Strategy 6:

In this strategy [17], an approach called complete adaptive is proposed. Periodic GW\_ADV messages are sent at large intervals and the periodicity is adapted whenever mobility is detected in the MANET. To decide the TTL of the GW\_ADV message maximal benefit coverage algorithm [13] is used. In order to decide whether to perform adapt TTL periodicity, a heuristic function is used. At regular intervals, each gateway calculates its regulated mobility degree (RMD), which gives the amount of mobility of the source nodes registered with this gateway. The RMD parameter is used as a threshold value to determine whether to adapt the periodicity of the GW\_ADV message. If an adaptation is required, it is done according to the maximal benefit coverage algorithm, as stated earlier.

#### Strategy 7:

This gateway discovery scheme [18] is suitable for real-time applications. It adjusts the frequency of GW\_ADV messages dynamically.

The GW\_ADV time interval is associated with the quality of service of the traffic. Whenever a source node chooses to send real-time traffic, if the real-time traffic is not delivered within a stipulated time period, the destination sends a QoS\_LOST message back to the source. Each gateway periodically checks if it has received a QoS\_LOST message in the last  $\tau$  seconds from an active real-time traffic source. If it has not received, then the gateway sends a GW\_ADV message.



Otherwise, the gateway calculates the ratio of the number of real-time traffic sources which are experiencing end-to-end delay, to the total number of real-time sources using that gateway. This ratio is used as a threshold to decide whether to send a new GW\_ADV message. The TTL is not adjusted dynamically in this strategy.

*Strategy 8:*

In this strategy [19] a load-adaptive access gateway (AG) discovery scheme is proposed which dynamically resizes the range of proactive AG advertisements and reduces AG acquisition latency.

Computation of proactive area: The AG periodically broadcasts Access Gateway Advertisements (AGA) containing its load information. These advertisements are limited within n-hop neighborhood using a TTL field. In order to adjust this area dynamically, AG should know the following information: The number of network nodes, the number of source nodes that want internet connectivity, the size of the network. It is assumed that the AG estimates the size of network and the number of nodes. The initial proactive area is calculated using the following equation.

The proactive range increases or decreases according to the network traffic which is estimated by AG during a time interval. While this strategy takes into account the load of the network while calculating the TTL value dynamically, it fails to address the problem of periodicity of GW\_ADV messages.

*Strategy 9:*

In this strategy [20], a novel genetic algorithm is used to adjust the GW\_ADV time interval,  $T_{MRA}$ . The proactive gateway discovery mechanism is used for GW\_ADV range. An estimation of the percentage of nodes located in the transmission range of the gateway is used to regulate the periodicity of GW\_ADV message. Dense neighborhood of a gateway indicates that the number of hops is more, therefore, GW\_ADV messages must be sent at lengthier time intervals, resulting in higher value of periodicity  $T_{MRA}$ , in order not to congest the MANET with unnecessary control messages.

The value of  $T_{MRA}$  is configured using a control system which uses a genetic algorithm, which works on the basis of a fitness function. The fitness function judges the suitability of the  $T_{MRA}$  value and is based on packet loss rate and end-to-end delay, which are perceived as the two most crucial parameters by end users. Based on the fitness function, the value of  $T_{MRA}$  is fine tuned to reflect the changing network topology.

*Strategy 10:*

Maximum source coverage scheme may not be applicable to all scenarios since one part of the network may be highly loaded and other part may be lightly loaded. A new scheme called Adaptive Distributed Gateway Discovery (ADD) [21] is proposed which is based on the hypothesis that gateway advertisements should be targeted at active sources and

not at other nodes. Instead of adjusting TTL at the gateway, a distributed approach is used.

To begin with TTL = 0 and a completely reactive approach is used. A mobile node which desires Internet connectivity sends a GW\_SOL message to discover a gateway. The gateway responds with GW\_ADV. The GW\_SOL message passes through multiple hops to reach the gateway. Each intermediate node through which it passes marks itself as an intermediate node. When the GW\_ADV is sent by the gateway, it sets TTL = 1. This message is received by mobile nodes which are one hop away from the gateway. Among these neighboring nodes, some may have marked themselves as intermediate nodes when the GW\_SOL message passed through them. These nodes reset the TTL as 1 and again forward it to their neighbors. Other nodes which are not marked intermediate decrement the TTL value and throw away the message. Therefore, only intermediate nodes receive GW\_ADV messages and the forward the GW\_ADV by resetting TTL=1. In this way, only those active nodes desirous of maintaining connectivity with the gateway are periodically sent the GW\_ADV and all other nodes are not burdened. The set of intermediate nodes is called an active region. When a node moves, its active region also moves.

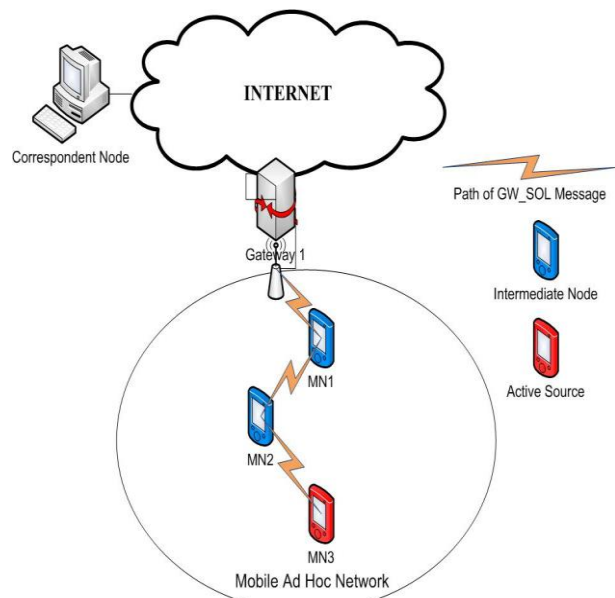


Figure 4. Working of Adaptive Distributed Gateway Discovery

In fig 4, MN 3 solicits Internet connectivity by sending a GW\_SOL message to the gateway. The set of nodes through which this GW\_SOL message passes through, i.e. MN 1 and MN 2, mark themselves as intermediate nodes. When the GW\_SOL message reaches the gateway, it sends GW\_ADV message to its neighbor MN 1 with TTL =1. Now, only MN 2 resets TTL value to 1 and forwards it, since it is an intermediate node. The other gateway neighbors set TTL = 0 and throw it away since they are not an intermediate node.

*Strategy 11:*

In this strategy [22], the authors contend that the optimal TTL value depends on the particular scenario and network conditions. A futuristic architecture combining cellular and WLAN networks is proposed in which each base station or gateway decides its TTL value independently according to the link quality as well as density of active source nodes in the network.

In this strategy, a novel method of adjusting TTL value was proposed which can be an alternative to the maximal source coverage method. Periodicity of GW\_ADV is not addressed.

Adjustment of the TTL value results in the proactive zone adjustment. Adjustment of the TTL value is based on the changes in average distance of active sources from the gateways and the signal strength of the gateways. Periodicity of GW\_ADV messages is not addressed.

*Strategy 12:*

In this proposal [23], the gateway periodically generates modified router advertisement (MRA) messages each interval of time  $T_{MRA}$ . An MRA message is nothing but a GW\_ADV message. These messages are propagated in a restricted area close to the gateway (proactive zone). This area is defined by the TTL value. Gateway solicitation messages generated by mobile nodes in the reactive zone are called Modified Router Solicitation (MRS) messages, which are nothing but GW\_SOL messages. The optimum value for  $T_{MRA}$  and TTL depends on the network conditions such as load etc. The objective of this work is to analyze the benefits of dynamically adjusting the  $T_{MRA}$  and TTL values in a hybrid gateway discovery.

The scheme is based on estimating the number of Modified Router Solicitation (MRS) messages generated by the mobile nodes in an interval of time called MRSCOUNT or  $T_{MRS}$ . Based on the  $T_{MRS}$  messages received, the gateway predicts how many MRS requests it will receive in the next  $T_{MRS}$  interval.

The Maximal Source Coverage algorithm is used to set the TTL value.

*Strategy 13:*

There is a need for gateway discovery mechanisms that support several Heterogeneous Wireless and Mobile Networks (HWMN) applications. Recognizing this need, this strategy [24] is based on HWMN architecture. Vehicular Ad Hoc Network (VANET) is considered as a multi-hop network, as an alternative to Mobile Ad Hoc Network (MANET). In this architecture, the proposed protocol is a layer on top of the network layer. It uses channel diversity and adapts the advertisement zone of the gateways based on the location information and velocity of the mobile nodes. This mechanism is called location aided adaptation of the advertisement of the gateway.

It is assumed that the gateway recognizes the location  $L_0$  of the source vehicle S at time  $t_0$ . The gateway can discover this information from the GW\_SOL message

sent by a vehicle. From the Gateway's point of view, the expected area of the source vehicle S, which has sent the GW\_SOL message, at time  $t_1$ , is the area in which S is expected at time  $t_1$ . In addition, G is also supposed to know the velocity of S at time  $t_0$ . Then, the expected zone of S at  $t_1$  is the circle of radius  $(t_1 - t_0) \cdot v$  centered at the location  $L_0$ .

In this way, the gateway can adapt its proactive advertisement zone to include the source vehicle (mobile node). The periodicity of the GW\_ADV message is not addressed.

*Strategy 14:*

A dynamic algorithm is proposed [25] based on the fuzzy system which controls the periodicity and value of the TTL. A gateway generates periodic Modified Router Advertisements (MRA) in the proactive zone. Mobile nodes outside this zone generate Modified Router Solicitation (MRS) messages. The following parameters are used:

Number of received MRS (NMRS): It is the ratio of the number of MRS messages that the sources generate and the number of active sources.

Link Changes (LC): This metric is used to measure the mobility of nodes near the gateway. It represents the ration of number of link changes a gateway detects and the number of active sources.

TTL changes (TTLC): This metric represents the ratio of number of changes in the distance of the active sources to the number of active sources.

In essence, NMRS calculates the ratio of active sources in the reactive zone and proactive zone. LC calculates the mobility of nodes near the gateway. TTLC calculates the mobility of active sources. The above three parameters are fuzzified. Based on their values, the parameters can be classified as low, moderate and high. The authors present fuzzy rules. Based on these rules, an output called convenience is produced, which can have values very low, low, moderate, high, very high. The value of the output is compared with a predetermined threshold (0.5). When it exceeds the threshold, the gateway concludes that an MRA message is necessary and broadcasts a new one. The parameters are measured each second so that the algorithm is able to adapt itself to rapid changes in the movement of nodes. The decision phase is triggered every second with updated measurements.

This algorithm only calculates the periodicity of the TTL. For value of the TTL, maximal source coverage algorithm is used.

*Strategy 15:*

In this strategy [26], both TTL value and periodicity of GW\_ADV message are adjusted dynamically. In addition, the novelty of this strategy lies in the fact that unidirectional links are not considered while forwarding packets between mobile nodes.

To calculate the TTL value of the next GW\_ADV message, the average number of hops of all source nodes is considered, as in the previous strategy. The difference between the average numbers of hops of two

successive GW\_ADV messages is added to the TTL value of the previous GW\_ADV message which results in the value of the next TTL.

V. COMPARISON FRAMEWORK OF ADAPTIVE GATEWAY DISCOVERY MECHANISMS

In this section we provide a framework for the comparison of the Adaptive Gateway Discovery mechanisms discussed in section IV. The adaptive gateway discovery strategies can be classified into the following three types: We call the strategies which adjust the TTL value only as Type A, those which adjust the periodicity of the TTL value only as Type B, and those which adjust both the TTL value and its periodicity Type C. Fig 5 provides a classification of the adaptive gateway discovery mechanisms based on the above classification.

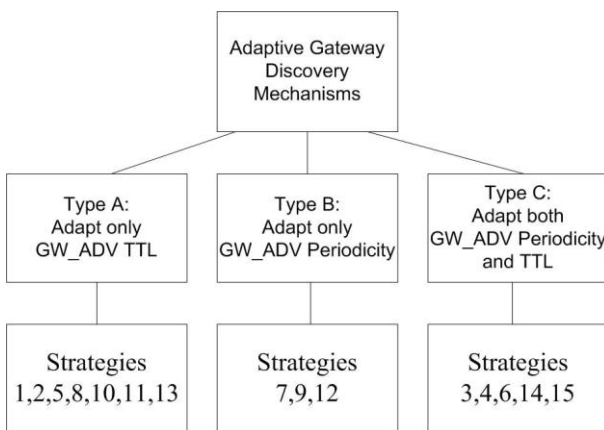


Fig 5. Classification of Adaptive Gateway Discovery Mechanisms

The adaptive gateway discovery mechanisms discussed in this paper use different parameters for adapting the GW\_ADV TTL value and GW\_ADV Periodicity. The parameters used by each strategy are listed in Table I. From Table I, we observe that the Maximal Source Coverage and Maximal Benefit Coverage algorithms are frequently used for GW\_ADV TTL adjustment. Strategies 4 and 6 use the mobility degree to determine the GW\_ADV periodicity. Only one strategy (strategy 7) uses QoS parameters for adjusting either of the two GW\_ADV parameters.

Tables II, III and IV present the mobile ad hoc network routing protocol and type of architecture of Type A,B and C adaptive gateway discovery strategies. From these tables, we observe that most of the strategies use AODV routing protocol or its extended version AODV+ for MANET routing. Almost all the strategies use the Internet integrated MANET architecture, and only two strategies (11 and 13) use a different architecture. In Table II, MUN stands for Mobile Ubiquitous Network and HWMN stands for Heterogeneous Wireless Mobile Network.

TABLE I. GW\_ADV TTL AND PERIODICITY PARAMETERS OF ADAPTIVE GATEWAY DISCOVERY MECHANISMS

Adaptive Gateway Discovery	GW_ADV TTL Value	GW_ADV Periodicity
Strategy 1	Maximal Source Coverage	-----
Strategy 2	Maximal Benefit Coverage	-----
Strategy 3	Average number of hops	
Strategy 4	Number of hops of source nodes	Movement Degree
Strategy 5	Number of source nodes	-----
Strategy 6	Maximal Benefit Coverage	Regulated mobility degree (RMD)
Strategy 7	-----	QoS parameters(End-to-End delay)
Strategy 8	Network size, number of nodes and data packet size	-----
Strategy 9	-----	Genetic algorithm based on packet-loss-rate and end-to-end delay
Strategy 10	Calculated at each hop	-----
Strategy 11	Signal quality, average hops to active sources	-----
Strategy 12	-----	Estimating number of MRS messages
Strategy 13	Location and velocity of mobile node	-----
Strategy 14	Maximal Source Coverage	Fuzzy mechanism based on NMRS, LC, TTLC
Strategy 15	Average number of hops of all source nodes	

TABLE II. COMPARISON OF TYPE A STRATEGIES

Adaptive Gateway Discovery	MANET Routing Protocol	Type of Architecture
Strategy 1	AODV	IIM
Strategy 2	AODV	IIM
Strategy 5	AODV	IIM
Strategy 8	AODV+	IIM
Strategy 10	AODV+	IIM
Strategy 11	DSR	MUN
Strategy 13	LAGAD	HWMN

TABLE III. COMPARISON OF TYPE B STRATEGIES

Adaptive Gateway Discovery	MANET Routing Protocol	Type of Architecture
Strategy 7	AODV	IIM
Strategy 9	AODV+	IIM
Strategy 12	AODV+	IIM

TABLE IV. COMPARISON OF TYPE C STRATEGIES

Adaptive Gateway Discovery	MANET Routing Protocol	Type of Architecture
Strategy 3	AODV	IIM
Strategy 4	AODV+	IIM
Strategy 6	AODV	IIM
Strategy 14	AODV+	IIM
Strategy 15	AODV	IIM

## VI. CONCLUSION

In this paper, we have presented a survey of adaptive gateway discovery mechanisms in heterogeneous networks. We have classified the adaptive gateway discovery mechanisms into three types based on the parameters GW\_ADV periodicity and TTL. We summarize that an ideal adaptive gateway discovery mechanism must address both the issues of dynamically adjusting the TTL value as well as the periodicity of GW\_ADV messages. Such a strategy must take into account network conditions like traffic load and node density, as well as signal strength. The adaptive gateway discovery strategy must not only address Internet integrated MANET, but must also work with more heterogeneous architectures envisage in future 4G networks [27].

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