A Hybrid Cooperative Service Discovery Scheme for Mobile Services in VANET

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***Abstract*— Discovering and accessing services while on the road is an important component in the architecture of future vehicular ad hoc networks, and for a successful deployment of services. Several studies have focused on the design and development of new routing and dissemination techniques that allow vehicles to communicate with each other and with road side units. However, detecting and reaching available services in a vehicular network remains problematic due to the amount of wireless traffic generated when service queries or advertisements are flooded across the network. In this paper, we propose a cooperative hybrid service discovery scheme for discovering services provided by mobile vehicles. This scheme is achieved through cooperating vehicles using store-and-forward approach and by sharing collected service information. We also propose to study the performance of the scheme by varying its degree of reactiveness and proactiveness. It is integrated with a caching mechanism which substantially improves the performance of the service discovery in terms of reduction of the traffic generated, and minimization of the response time while increasing the discovery success rate.**

Keywords-Vehicular networks; service discovery; caching;

I. INTRODUCTION

Vehicular Ad hoc Networks (VANETS) are network of interconnected and smart vehicles that are able to communicate with each other and exchange relevant information. The premier objective of VANETs is to expand the reach to Internet as well as to access available services while on the road. Vehicles are capable of establishing multi-hop communication links to other vehicles; a scenario referred to as vehicle-to-vehicle (V2V) communication, or to a road side unit (RSU) which is hosting a given service (V2R). Many applications are seeking to benefit from vehicular networks. Such applications include road safety where vehicles exchange timely information. Recently more focus has been put into dissemination protocols that are specific to road and travel-information applications including detecting road incidents, broadcasting alert messages and commercial advertisement, and accident avoidance. Various techniques and routing protocols have been developed to support such applications.

Nevertheless, it remains a challenging task to provide efficient information exchange over VANET with high accuracy and lesser response times. This is due to the short-lived connection links, frequent network disconnections, and a highly dynamic environment that characterizes vehicular networks. Furthermore, exchanging and sharing information between vehicles through the use of flooding and dissemination techniques often results in saturating the air resources with data and control messages redundantly and unnecessarily frequently broadcasted. Therefore new protocols have been developed to address these issues without undermining the support required for VANET applications and services. In this paper, we propose a service discovery scheme with the purpose of locating, and discovering services on VANET. We detail the discovery protocol and the communication structure supporting service discovery. In addition, we propose a caching mechanism to reduce the overhead represented by the amount of wireless traffic generated when service requests are broadcasted to discover these services. Thus, when information is fetched, intermediary vehicles store that information in a cache for future use. We present an evaluation of this mechanism and emphasize the interest of using caching mechanisms in distributing the description of the services over the network.

The remainder of this paper is organized as following: next section summarizes the existing work on service discovery in VANET. Section III details the service discovery scheme we have proposed including its system and the communication models. In section IV we describe the scheme we use to cache discovery information in intermediary nodes and its impact in improving the service discovery in VANET. In section V, we describe the performance results of our discovery technique. We conclude in section VI and highlight future work.

II. RELATED WORK

Service discovery in VANET has been recognized as a challenging research area as it is characterized by its dynamic and ad hoc nature. First, available services as well as the service providers may not be known ahead of time since vehicles are constantly moving into and out of different networks. Second, services and service providers may be formed and undone in an ad hoc way which makes it difficult for vehicles to keep track what is out there. Several research studies have been proposed to address service discovery in MANET [1-4]. These works are considered as the basis for service discovery in VANET as both environments exhibit similar features and pose similar challenges. However, VANET adds a new dimension of complexity mainly due to scalability and a higher mobility.

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In [5], the authors present an Internet gateway discovery protocol which is capable to choose the most suitable gateway using fuzzy methods. Here, the discovery method, named DRIVE, is rather proactive (referred to by the authors as “passive discovery”), and requires Internet gateways to advertise their presence to the vehicles. Compared to SLP [6], the evaluation of DRIVE shows a significant decrease in the overhead caused by the service discovery process. In [7], the authors present a fault tolerant location based service discovery protocol for VANET which has the ability to tolerate service providers failure, communication links failure and roadside routers failure. This scheme shows an improvement of the success rate even in the case of failure of roadside units or communication links.

In [8], the authors propose a new discovery protocol - called Address Based Service Resolution Protocol (ABSRP), which relies on roadside units to provide services. This technique proactively distributes the service provider's address along with its servicing capabilities to other roadside units within a particular area. The authors propose to use the backbone network if the service provider is not reachable over the vehicular network. The work in [9] presents a service discovery and propose a secure service access solution based on district domains which are entities responsible for dispatching session parameters on-demand to users. The purpose is to facilitate the delivery of secure information offered at the roadside infrastructure. In [10], the authors propose a location-based routing protocol which forwards data in a greedy way. The protocol uses a proactive routing scheme to find the destination information by flooding RREQ messages. They tried to maintain the routing overhead as low as possible. In [11], the paper proposes an agent based information dissemination model for VANETs. A two-tier agent architecture is employed comprising of a 'lightweight' network-facing with mobile agents, and a 'heavyweight' application-facing with norm-aware agents. The authors consider a hybrid network model based on LAN/Cellular and ad hoc networking for analyzing the proposed model. The latter provides flexibility, adaptability and maintainability for traffic information dissemination in VANETs as well as supports robust and agile network management. The architecture proposed in [12] includes a MAC layer protocol to support the multi-channel operation for DSRC. Here, the authors propose a service access solution for high-bandwidth non-safety applications provided by roadside infrastructure. When a vehicle approaches a DSRC service hot-spot, it switches from the ad-hoc mode to the coordinated mode. When a vehicle is not within the range of a DSRC hot-spot, the vehicle can use any of the previously-proposed ad-hoc protocols.

III. A COOPERATIVE SERVICE DISCOVERY: AN OVERVIEW

Although service discovery solutions are similar in fixed, mobile ad hoc and vehicular networks, each environment presents its own differences. Vehicular networks add to the problem the complexity related to the high mobility of the vehicles. In this scheme we address the class of vehicular networks where services are established and ridden of in an ad hoc way.

A. System Model

The service providers are themselves mobile. In the following we describe the architectural functions of our scheme. In this model we consider three functional elements:

- *Service Provider* (SP): it consists of any network element which is providing a service. SP can be hosted by a fixed element such as a server on the network backbone or a Road Side Unit (RSU), or by a mobile vehicle which is referred to as Mobile SP (MSP). In this study we focus mainly on the case of services provided by mobile vehicles.
- *Service Solicitor* (SS): It consists of vehicles on the road which are requesting access to services provided by the SPs on the VANET.
- *Service Broker* (SB): this refers to special servers whose main service is to inform SSs with the details of the services requested and those of the server providers themselves. SBs are in effect service providers. Just like SPs, brokers can be fixed or mobile (MSBs). In this last case, MSBs are hosted by vehicles on the road.
- *Proxy Agent* (PA): this refers to a vehicle which can store information related to services available in the network and responds to solicitors on behalf of the service providers.

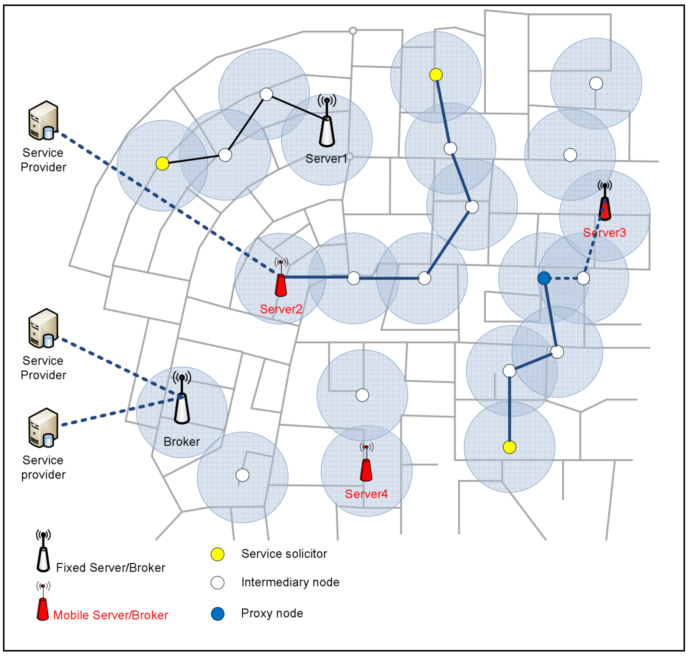

Figure 1. Service discovery in VANET

Since the vehicles are constantly moving, the network topology keeps changing dynamically, and therefore leading to service solicitors losing track of the whereabouts of the services. In this case, SS will broadcast a query requesting information about the service solicited. In successful cases, either the service provider will get the request and accommodate the solicitor by responding to it, or the request will reach a broker which actually knows about the service solicited and about those servers which can provide it; in which case it responds to the solicitor by providing it with the necessary details to access it through other ways. This model is not different from that advocated by the service-oriented architectures thoroughly studied in the literature [13]. However, the main difference here, is the highly dynamic communication environment which makes no assumption about the stability of the location of the servers or the brokers. Many research studies have addressed the problem of discovering services in vehicular networks resulting in several mechanisms and protocols with varying performance results. The most challenging performance aspects are the success rate and the response time. In all of these studies, the brokers and the service providers are considered as fixed nodes in the network and hosted either by the RSUs or even in the backbone. In our model, we consider both server providers and brokers as possibly hosted by mobile vehicles.

B. Communication Model

The communication between the three types of elements is modeled through a pull-based geocast protocol. The service discovery process consists of the service solicitor broadcasting a service query by specifying the service solicited. The service query message (SQM) is received by neighboring vehicles and re-broadcasted until it reaches a vehicle that can provide that service or a vehicle that knows who can provide that service. In both cases, the vehicle having that information will respond by sending a service reply message (SRM). SRM messages are forwarded back to the service solicitor following the reverse path that the query has taken. As it is the case in geocast protocols, this requires that intermediary vehicles, stores in their routing table the node where the query came from as the next hop to the service solicitor.

Similarly, when a node receives an SRM – on its route to the solicitor, the node updates its routing table with the previous hop as being the next hop in the forward path to the node that responded with the SRM. The update procedure of the routing table for the forward path and reverse path is illustrated in Fig 2. Although most geocast protocols use the concept of *zone of relevance* (ZOR) to constrain the scope of the message propagation, we chose to rather use a maximum-hop approach (MAX_HOP) to stop the flooding of service discovery queries hops lesser than MAX_HOP. In addition to the use of the MAX_HOP approach, we have integrated the geocast protocol with a caching mechanism which contributes further in limiting the flooding overhead. In the following section, we describe further the caching mechanism and its expected benefits.

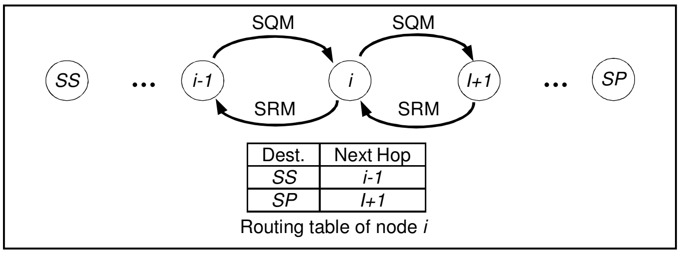

Figure 2. Relaying queries and forwarding response

IV. GEOCACHING THE SERVICES

The need for caching information transiting through intermediary nodes is justified by the substantial benefits gained in scaling information dissemination in vehicular networks. In our previous work [14], we have showed how caching contributes in improving the collection and sharing of road congestion information. We showed how geocache scheme can considerably improve the performance by reducing the total number of messages generated and the response time when information sought at a remote node can be found cached at a much closer node. Fig. 3 illustrates the operating details of this caching mechanism used in our discovery scheme.

The cache is organized by using a hash function which maps keys into a node location: *hash*(*key*)→*loc*. In our case, a hash key represents a solicited service identified by *sid*, and the location represents the server providers identified by *servid*; that is: *hash*(*sid*)→*servid*. Each key in the table has an expiry time T_e after which the key is removed from the cache. Keys in the table are refreshed every time a node encounters a SRM following its reverse path towards the service solicitor. Each vehicle in the system hosts and maintains a cache including the vehicles which are neither seeking nor providing services. A vehicle which may have a special interest in collecting and maintaining information about all the services that are being offered make special provision for extra arrangements such as a bigger size of the cache and a smarter management of the caching procedure. These vehicles are referred to as *service proxies*.

It is worth noting that the choice of the right value for the cache expiry time is application dependent and has, therefore, to be selected carefully. One may think that for versatile services where service providers may change location or status very often, this parameter should be within the range of seconds. However, for services for which providers play their role for a longer period of time, the expiry time may reasonably be configured within a range of minutes.

Algorithm: Caching procedure

s_i: Service ID
$Descr(s_i)$: Description of the service solicited
T_{cur}: Current time
T_c: time associated with cache entry for the service description
T_e: the cache expiry time of the entries in the cache
$SQM(ss, s_i)$: Service query message from service solisitor ss for service s_i
$SRM(ss, Descr(s_i))$: Service response message sent back to *ss*
B_hops: Current number of hops traversed by the broadcast

When vehicle *V* receives $SQM(ss, s_i)$ from *ss*:
if (s_i exists in cache)
  if ($T_{cur} < T_e + T_c$)
  then
    send $SRM(Descr(s_i))$ to *ss*;
  endif
else if (*B_hops* < MAX_HOPS)
    then
      Broadcast $SQM(ss, s_i)$ to neighboring vehicles
    endif
endif

When vehicle *V* receives $SRM(ss, Descr(s_i))$
if (s_i does not exist in cache)
then
  update cache*:* $cache([hash(s_i)]) = <Descr(s_i), T_{cur}>$;
else
  update cache time with T_{cur};
endif
send $SRM(Descr(s_i))$ to *ss*;

Figure 3. Caching procedure

V. PERFORMANCE RESULTS

The cooperative discovery scheme was validated through simulation using the Java-based simulation. The simulation model includes a map representing a small urban area stretching over 4km×7km. For the results presented below, all the simulations are run for a simulated time of 30mn under the parameters indicated in Table 1. We used the same trace generated randomly based on the map used. For the mobility we have opted for the urban mobility model where vehicles are generated randomly with a Poissonian arrival time, with a random departure and destination points. The vehicles use a shortest path towards their final destination. By default, vehicles drive at a maximum velocity and decelerate when approaching either a slower vehicle, or an intersection ahead. In our model, vehicles are not allowed to overtake other vehicles and are required to maintain a *safe following distance* (3-second rule). Road sections are single-lane and bidirectional. We follow the *stop sign model* where a vehicle approaching an intersection decelerates until it reaches the intersection where it stops for a configurable time period (5 to 20 seconds). The deceleration is proportional to the distance left to the next intersection, or to the vehicle ahead. Each intersection may be configured to be a simple junction with stop sign, a roundabout or a junction with traffic light. For the included evaluations, we only considered roundabout junctions.

TABLE I. SIMULATION SETTINGS

Parameter	**Value**
Urban Area	4km × 7km
Number of intersections	24
Number of road sections	52
Simulated time	30mn
Maximum velocity	120kmph
Radio range	[200 m – 400 m]
Vehicle density	[100 – 500]
Navigation method	Shortest route
Maximum hops	5
Cache expiry time	[0mn – 5mn]
Number of service providers	[5-50]
Number of service solicitors	[5-50]

A. Simulation Scenarios

The objective of the simulation is to substantiate the claims stated earlier in the paper and summarized as follows: (1) Caching reduces the amount of messages generated due to the propagation of discovery queries; (2) The discovery response time represented by the detection and access of service providers is substantially improved; (3) In a correlated way, caching also considerably improves the success rate of service discoveries. The following criteria are used to assess the above claims:

- *Average number of messages generated per discovery*: The purpose of this criterion is to highlight the contrast between the performance of the system with and without caching. This average is calculated as the ratio of the total messages generated in the system and the number of service discoveries initiated.
- *Response time*: that is the delay between the time an SQM is sent and the time a first SRM is received.
- *Discovery success rate*: This criterion reflects the amount of services discoveries initiated that came to term successfully. It is calculated as the ratio of the total number of successful discoveries initiated and the total number of discoveries initiated.
- *Cache hit ratio*: this reflects the amount of successful discoveries that are the result of service cached at an intermediary node. It is calculated as the ratio of the total number of successful discoveries cached and the overall total number of successful discoveries.

TABLE II. COMMON RESULTS

Av. nb. of vehicles in the system	1276.48
Av. travel time	03mn 13sec
Av. nb. of communication hops	2.55

B. Simulation Results

The common results of all simulations carried out are illustrated in Table II. Since our focus is on the study of the effect of caching on the performance of our scheme, the results we present in this paper are based mostly on the variation of the cache time (indicated here by *CT*). Note that a scheme where *CT*=0 corresponds to a non-caching scheme since the caching time is nil.

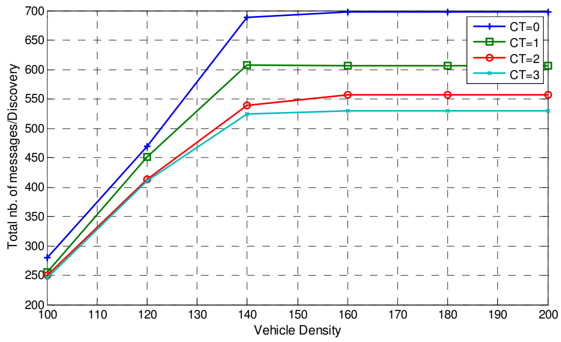

Figure 4. Average number of messages per discovery (radio range=300m, dissimation TTL=10 hops)

The performance of our scheme in terms of number of messages generated due to the dissemination of discovery queries is illustrated in Fig 4. It shows how caching can reduce the number of disseminated messages. It also shows that the trend is that the bigger is the cache expiry time (*CT*); the lower is the number of messages generated.

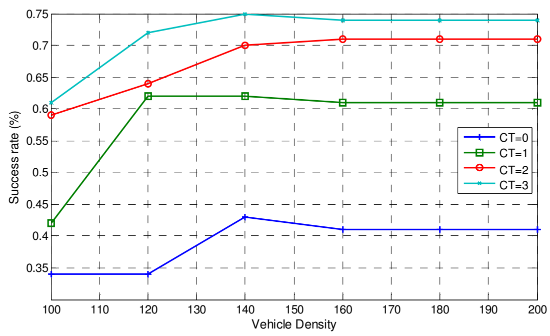

Figure 5. Discovery success rate (radio range=300m, dissimation TTL=10 hops)

In term of the amount of successful discoveries, the performance gained by our scheme when using caching is substantial. As indicated in Fig. 5, the gain is at least 10% (density=170) and gets higher as the vehicle density increases, 30% (density=200). This result also indicates that higher cache expiry times lead to higher gain in the successful discoveries.

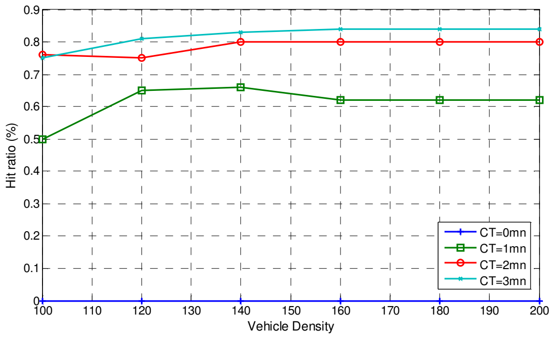

Figure 6. Cache hit ratio
(radio range=300m, dissimation TTL=10 hops)

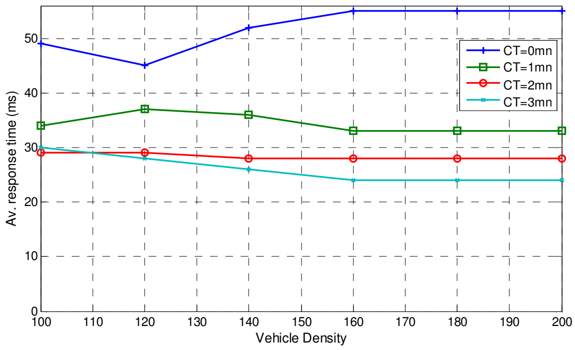

Figure 7. Average response time
(radio range=300m, dissimation TTL=10 hops)

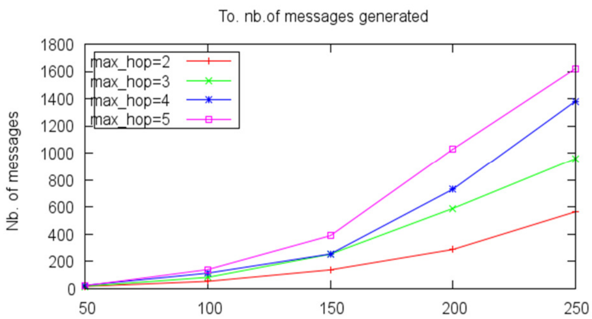

Figure 8. Number of discovery messages vs. vehicle density

The cache hit ratio is an important indicator in selecting the best value for the cache expiry time. Fig. 6 shows a slight difference in the hit ratio for the different expiry times used. This difference gets even smaller as the density of the vehicles increases. However, note that the difference between *ct*=1mn and the other values is more apparent. This is explained by the fact that due to the limited distance traveled in average by a vehicle, and therefore the small travel time (3mn) to get from the origin to the final destination, and the small average number of hops a discovery gets through (see Tab. II), the cache expiry time becomes irrelevant beyond a certain value (here 2mn).

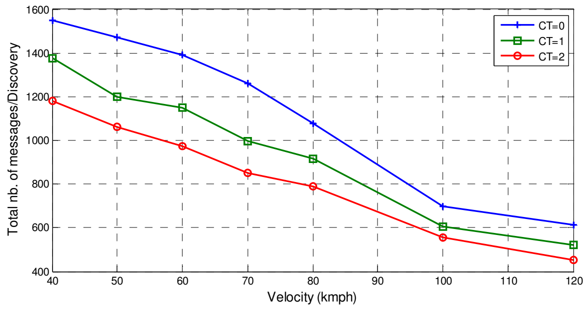

Figure 9. Impact of the velocity on the number query messages

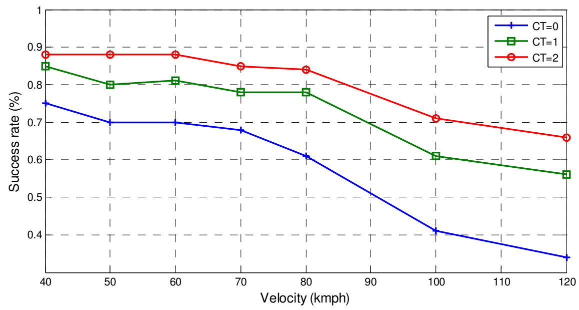

Figure 10. Impact of the velocity on the discovery success rate

As for the response time, Fig. 7 clearly indicates the advantage of caching. A cache expiry time of 1mn only (i.e., the worst case) results in a substantial reduction of the response time (i.e., at least 36%). Here again, and similarly to the hit rate, we see that little impact is made by the value of the cache time when selected beyond 2mn. The effect of the MAX_HOP value on the total number of generated messages is illustrated in Fig. 8. It shows that the bigger is the MAX_HOP, the bigger is the amount of messages generated. This number is amplified by factor when the density of vehicles in the system increases.

C. *Impact of the vehicles' velocity*

In this section, a general observation is that the velocity of the vehicles has little impact on most performance criteria except for on the number of query messages generated and the success rate. Both decrease when vehicles are moving faster. Fig-9 illustrates the extent of the impact of velocity on the number of message. This can be explained by the fact that faster the vehicles are moving, the more disconnected they become, and consequently the lesser is the number of query messages generated. This fact is also confirmed by the decreasing success rate observed and illustrated in Fig-10.

An interesting fact is that the vehicles' velocity has little impact on the cache hit ratio as shown by the results in Fig-11. Cache hits being obtained solely when successful discovery are completed, their trend is maintained regardless of the vehicles' velocity and success ration obtained.

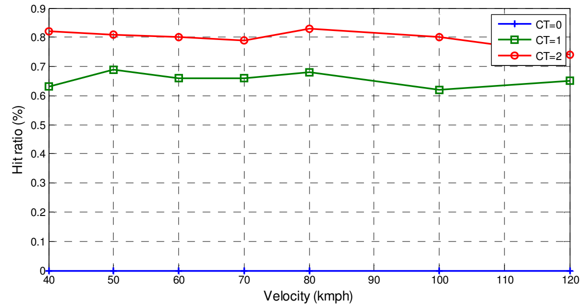

Figure 11. Impact of the velocity on the cache hit ratio

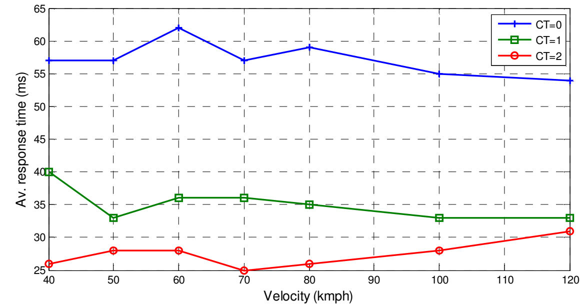

Figure 12. Impact of the velocity on the response time

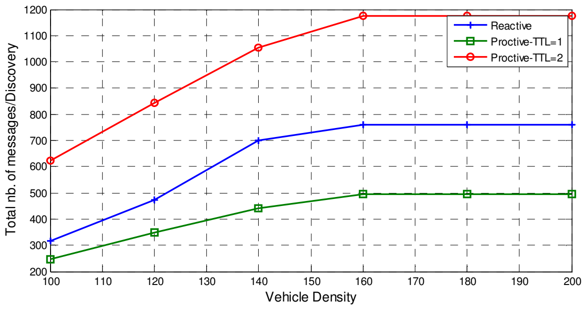

Figure 13. Comparison of the number of messages per signle discovery in the three discovery schemes (Advertisment frequency=10mn)

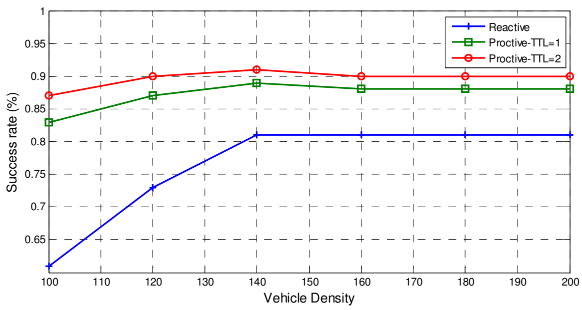

Figure 14. Comparison of discovery success rate in the three discovery schemes (Advertisment frequency=10mn)

As stated earlier in this section, here too the vehicles'' velocity seems to have little impact on the response time. This correlates well with the fact that when discoveries are successful they seem to have the same performance in terms of response time and hit ration for various speed averages of the vehicles (Fig-12). We should note here that these observations do not take into consideration the effect of the velocity on the radio frequency dynamics such as that of fast fading on the connectivity between moving vehicles. Here we merely considered the effect of the time duration a connection may be maintained between vehicles.

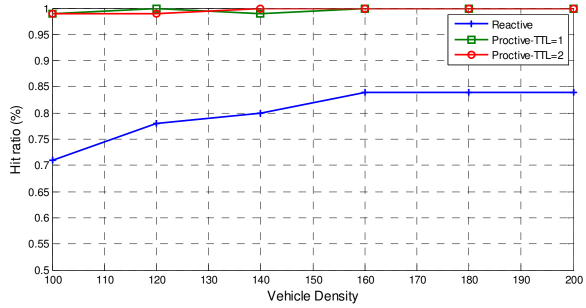

Figure 15. Comparison of the cache hit ratio in the three discovery schemes (Advertisment frequency=10mn)

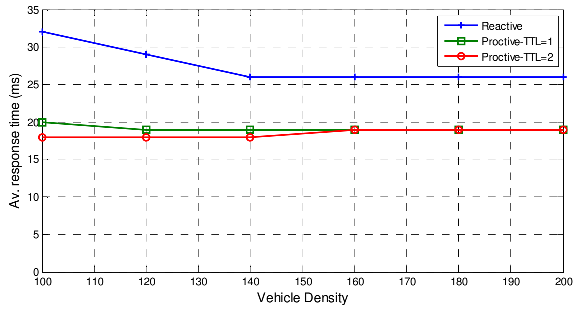

Figure 16. Comparison of the response time in the three discovery schemes (Advertisment frequency=10mn)

D. *Proactive scheme*

In this section we assess and discuss the performance of our scheme when supported by periodic service advertisements. Here, in addition to the initial scheme, we allow service providers and service brokers to periodically advertise the services they offer. We refer to our initial scheme without service announcements from the servers as "reactive". When the scheme is supported with periodic announcements that are broadcasted within a TTL range equal to 1 and 2, we refer to the scheme, respectively as "Proactive-TTL=1", and "Proactive-TTL=2". Here TTL refers to the depth of the dissemination of the advertisement messages in terms of number of hops to be covered by the broadcast. We have chosen an advertisement frequency equal from 10mn to 20mn for both proactive schemes.

In the following, we explain the results by comparing the three schemes in terms of the performance criteria stated earlier. Fig-13 shows that despite the fact that the scheme "Proactive-TTL=1" cause additional messages generated, the total number of messages per a single discovery remains lower than that of "Reactive". This is due to the fact that periodic advertisements allows service information cached in the vehicles to be refreshed frequently and therefore allowing service solicitors to reach them in a lesser number of messages generated. However, as we can see in the same figure, "Proactive-TTL=2" has not necessarily sustained the same performance due to the extra depth allowed for flooding the advertisements and consequently for a lot bigger extra number of messages generated.

The benefit brought about by integrating more proactiveness to our scheme is more clearly illustrated in Fig-14, where we can see an improvement in the discovery success. This rate is proportional to the TTL selected (1 and 2). However, one has to note that despite the higher gain obtained by periodically advertising service information to the neighboring vehicles, the gain incurred by increasing the TTL is not significant considering the cost in terms of number of messages generated.

As for the hit ratio, here again, properly combing reactive and proactive schemes in discovering services amplifies the benefit of using caching mechanisms and improve the hit ratio. As illustrated in Fig-15, both TTL values can invariably reach near-perfect hit ratios. Similarly, the response time is substantially improved and in the same way by using proactive schemes with any of the values of TTL.

Fig-16 shows that the proactive scheme improves substantially the response time. The results also show that both values of the TTL result in the same performance.

In conclusion, adding proactiveness to the scheme improves the performance of our scheme in all aspects. The results also show that beyond the value 1 of the TTL, proactiveness result in the same performance but with an increasing cost in terms of network overhead as the TTL increases.

VI. CONCLUSION

In this paper we have presented a new scheme based on a pull-based geocast protocol for discovering mobile services available in a vehicular network. Integrated with a caching mechanism, we showed that collected information about the services offered and the service providers can be shared and exchanged in an efficient way. We have showed that caching can also be useful in constraining the scope of the dissemination just as the MAX_HOP factor does for the dissemination protocols in limiting the flooding of messages. We have presented performance results that substantiate our claims for the use of a hybrid approach with TTL=1, and of caching and its effect in improving the process of service discovery in terms of reduction of the total number of broadcast messages generated and the response time while increasing the discovery success rate.

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