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Cluster-based location service schemes in VANETs: current state, challenges and future directions

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Abstract
Vehicular Ad hoc Networks (VANETs) have drawn incredible interest in both academic and industrial sectors due to their potential applications and services. Vehicles' position plays a significant role in many location-based applications and services such as public emergency, vehicles tracking, resource discovery, traffic monitoring and position-based routing. A location service is used to keep up-to-date records of current positions of vehicles. However, locating vehicles' positions and maintaining an accurate view of the entire network are quite challenging tasks due to the high number of nodes, and high and fast nodes mobility which results in rapid topological changes and sudden network disconnections. In the past literature, various location-based services have been proposed to solve the above mentioned issues. Moreover, the cluster-based location service schemes have gained a growing interest due to their advantages over non-cluster-based schemes. The cluster-based schemes improve the network scalability, reduce the communications overhead and resolve the mobility issues within the clusters preventing them from propagating in the whole network. Therefore, this paper presents the taxonomy of the existing location service schemes, inspects the cluster-based location service by highlighting their strengths and limitations, and provides a comparison between location-based clustering and application specific clustering such as the one used in routing, information dissemination, channel access management and security. In addition, the existing clustering schemes, challenges and future directions for efficient cluster-based location service are also discussed.

Keywords VANETs · Clustering · Location service · Cluster-based location service · Position-based routing

1 Introduction

VANETs have recently gained attention as an emerging and stimulating class of Mobile Ad Hoc Networks (MANETs). In VANETs, vehicles communicate with each other using Vehicle to Vehicle (V2V) communication or with the Road Side Units (RSUs) through Vehicle to Infrastructure (V2I) communication. VANETs are becoming an integral part of smart city and Intelligent Transportation System (ITS) applications and services. In fact, VANETs enhance the performance of ITS via providing services in terms of finding the closest parking slot, gas station or restaurant and discovering the position of any other vehicle including emergency vehicles, patrolling police vehicles and resource discovery vehicles. These services mainly depend on obtaining the accurate location of the service provider. Location service is one of the essential applications in vehicular networks to provide the location of a requested service [1–3].

In VANETs, a routing protocol plays very significant role in providing various services by exchanging the messages between nodes. There are two types of routing protocols proposed for VANETs such as Topological Routing Protocols (TRPs) and Geographic Routing Protocols (GRPs). TRPs maintain the link information and broadcast the topology information to forward the packets. TRPs suffer from high control overhead, lack of scalability, heavy discovery and maintenance phases. However, GRPs depends on the up-to-date location of the vehicles to forward the packets and do not require routing tables. There is no need to maintain and exchange the link information. GRPs are suitable for large scale dynamic networks due to their simplicity and low overhead. GRPs outperform the topological routing protocols in terms of scalability, performance and low routing overhead. One of the fundamental requirements of GRPs is to get the exact position of the vehicles and make routing decisions

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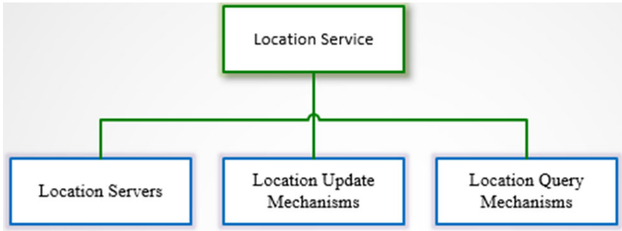

Fig. 1 Components of a location service [11]

based on the position of the destination vehicle. Every vehicle is equipped with a Global Positioning System (GPS) and a digital map. Every vehicle gets its position through a GPS and uses a location service to get the position of other vehicles. These positions are maintained by a location service. One of the important challenges in GRPs is the design of efficient location service to provide accurate and timely location information of requested vehicles. As a result, the performance of a GRP mainly depends on the performance of the location service [4–9].

Location service is a fundamental scheme which is used to record the current location of all vehicles in VANETs [10]. In a location service, vehicles' locations are stored using several servers which are connected through an infrastructure network. Periodically, every vehicle sends its updated position to a location server. Then the location server maintains the current location of vehicles. A location service is based on three components such as location servers, location update mechanisms and location query mechanisms as shown in Fig. 1.

The location service schemes are further divided into different categories such as flooding-based, rendezvous-based, quorum-based and hierarchical-based. The complete taxonomy of the location service is given in in Fig. 2. Moreover, the cluster-based location service schemes manage vehicles into clusters. In each cluster, one vehicle is elected as a Cluster Head (CH) using a predefined election mechanism. The CH broadcasts membership messages to affiliate the nearby vehicles as to be Cluster Members (CMs). CMs send their location information to the CH periodically. The CH keeps the record of location information of its CMs. The CH also sends the location information of its CMs to a high-level server which may be another moving vehicle or RSU.

A clustered network structure has been generally considered for use in a VANET because it provides more reliable connectivity for a group of vehicles. Clustering in VANETs, is an operative method that supports node coordination, reduces interference among nodes and improves the traffic management, routing, channel access management, provisioning of resources and bandwidth utilization. Managing vehicles within distributed clusters using hierarchical layout improves the scalability and reliability of VANETs. Since

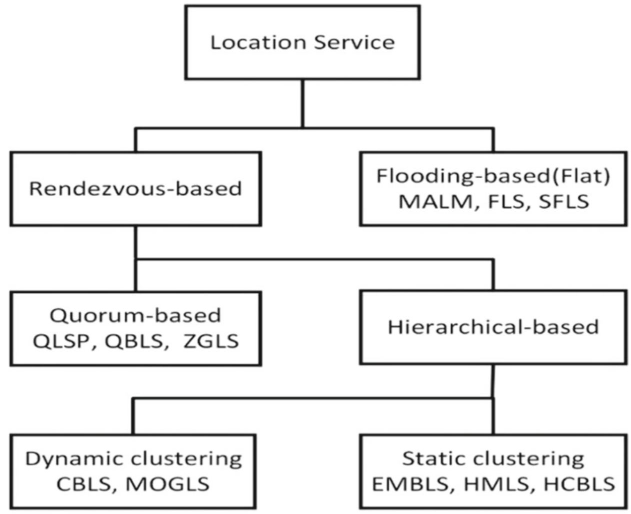

Fig. 2 Taxonomy of location service schemes

past few decades, clustering in VANETs is an active research area where a wide range of research work has been done [12–14].

In [15], the author has classified the existing location service schemes based on flooding, rendezvous, quorum and hierarchy. Reactive Location Service (RLS), Grid Location Service (GLS) and Hierarchical Location Service (HLS) schemes are critically analyzed considering the performance metrics: query success rate, overhead and request travel time.

In this review, existing hierarchical location service schemes are further divided into two categories based on static and dynamic clustering as shown in the Fig. 2. This review paper has critically analysed the existing location service schemes by mentioning the advantages and disadvantages of each category. Along with that, a detailed analysis and comparison of cluster-based location service have been elaborated. Likewise, a comparison between cluster-based location service and application specific clustering has been described as well. This paper also highlights the challenges that affect the performance of the cluster-based location service. The contributions of this review are as follows:

- Taxonomy of the existing location service schemes has been provided which categorizes the location service schemes based on various key parameters.
- A detailed discussion and comparison of cluster-based location service schemes have been provided.
- A critical analysis and comparison between clustering in specific applications and clustering in location service have been elaborated.
- Several critical issues, challenges and future directions have been highlighted in order to improve the performance of the cluster-based location service.

This paper is organized into six sections. Section 2 describes the taxonomy of the location service schemes. Section 3 describes cluster-based location service schemes. Section 4 gives a comparison of application-specific clustering and clustering for location service schemes. Section 5 highlights the challenges and future directions in cluster-based location service, followed by the conclusion in Sect. 6.

2 Location service schemes taxonomy

The classification of existing location service schemes can be viewed in Fig. 2. These location service schemes can be divided into two main categories: flooding-based and rendezvous-based schemes [15].

2.1 Flooding-based location service

In flooding-based location service each node periodically floods its location to update the location table of all other nodes in the network. When a node wants to communicate with a destination, it first checks its location table. If the location information is not available or is expired, then the source node floods a location query packet in the entire network. Both location updates and location queries are based on flooding. These schemes are also named as flat schemes [16, 17]. A Mobility-Assisted Location Management (MALM) consider the flooding approach to update the location of vehicles in the network. Every vehicle broadcasts its location to its neighbouring vehicles [18].

The scheme proposed by [17], tried to reduce the control overhead by disseminating the location up to 3-hop distance. A Semi-Flooding Location Service (SFLS) attempts to minimize the number of updates by employing a conditional update technique at the forwarder node [19]. When a node requires the position of another node, it disseminates a query using backbone vehicle until a backbone node which has the location is reached.

In [20], a scheme is proposed to control the flooding issue by reducing the number of packets sent. However, it has the network overhead issue, which needs to be solved. The selection of the next forwarder affects the flooding process. The current location and localization error are compromised via the location maximum updating delay. Moreover, in VANETs, most of the vehicles are registered in the neighboring table of more than one vehicles. Therefore, same packets are propagated multiple times that increases network overhead.

The Flooding-based location service makes use of flooding approach to distribute messages. The advantage of flooding-based solutions is that these are simple and also each node in the network is aware of the position of all the other nodes. Even so, flooding schemes are inefficient and not suitable for large scale networks, create scalability and network management problems. This approach suffers from high network congestion and low throughput [3, 21].

2.2 Rendezvous-based location service

A rendezvous-based location service makes use of location servers. A group of location servers are distributed over the whole network. These location servers store the position of all vehicles. Moreover, every vehicle updates its position to a location server that lies within its range. Rendezvous-based location service is further divided into two categories such as quorum-based and hierarchical-based [22].

2.2.1 Quorum-based location service

The quorum-based approach has been proposed to overcome the limitations of the flooding-based approach. The quorum-based approach uses the intersection point between a location query quorum and a location update quorum to provide the location service. The Quorum-based location service schemes form two groups of vehicles; an update quorum and a search quorum. The location of a vehicle is updated along the update quorum and a query for vehicle's location is sent along the search quorum, until it reaches at a vehicle which is at the intersection of both update and search quorum. Quorum-Based Location Service Protocol (QLSP) exploits road intersections as center point to define quorums [23]. Quorum-based location service (QBLS) is based on road properties to ensure an intersection point between a location update quorum and location query quorum [24]. Furthermore, the ZoomOut Geographic Location Service (ZGLS) makes use of whole network to build update quorum so that size of the query quorum may be reduced [25]. Location update and location query mechanisms are simple but have limitations during quorum construction phase. As a result, quorum-based location service schemes have quorum boundary issues and high quorum construction overheads which results in high communication overheads. ZGLS will not work properly in a sparse network without the availability of infrastructure nodes such as RSUs [4]. Quorum based solutions are not effective for VANETs due to their complexity in forming and maintaining quorums due to constraints like roads layout and void areas [16].

2.2.2 Hierarchical-based location service

Hierarchical-based location service works in multiple levels, specifically two or three levels, to manage the location of vehicles. A hierarchical network structure named cluster has been proposed for VANETs. Clustering is a process of grouping vehicles using predefined rules. These rules vary from algorithm to algorithm. There exists at least one CH

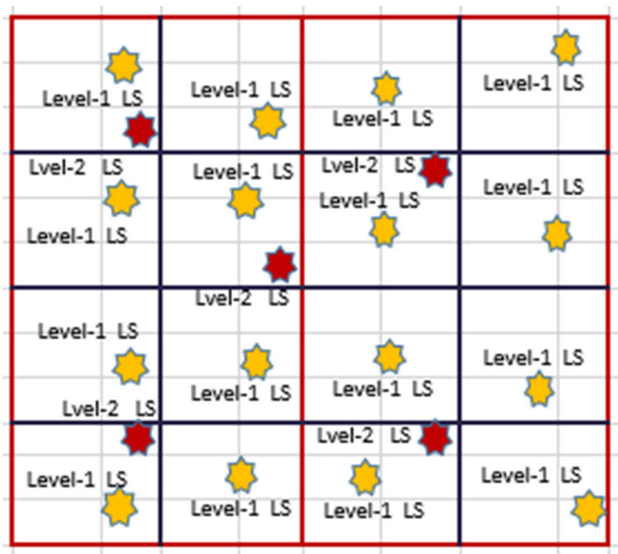

Fig. 3 Static clustering-based on area division [16]

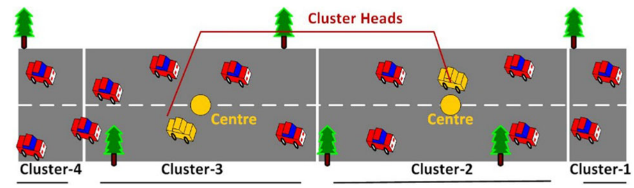

Fig. 4 Static clustering-based on road division [32]

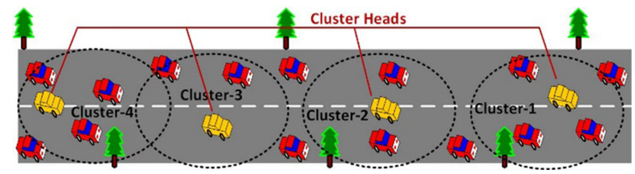

Fig. 5 Dynamic clustering-based on mobility

in every group, which is chosen from the vehicles based on some predefined criteria. After CH election, other vehicles join the group as CMs. The CH of a cluster is designated as a moving location server. It collects and keeps the locations of its CMs [26, 27].

Hierarchical-based location service incorporates one of two types of clustering, which are static and dynamic clustering. Static clustering is also known as physical clustering. In static clustering, the location of the cluster is predefined through dividing the area into fixed segments. The group of vehicles in that segment forms the cluster. In some cases, an RSU is also used to form static clusters. In addition, cluster formation is less complex but it suffers from a frequent CH change. The dynamic clustering is also termed as mobile clustering. It depends on the mobility parameters such as speed, position and direction of the vehicles to form clusters. The main advantage of dynamic clustering is the reduction of reclustering by moving the cluster with the vehicles [28–30].

In the static cluster-based location service [16, 21, 31], a geographical area partitioning technique is used to form the clusters. Two approaches are used to partition the geographical area. In the first approach, the whole city is divided into different regions as shown in Fig. 3. The highest level L3 covers the whole city. This area is further divided into level 2 geographical square partitions. Each level 2 square is further divided into the lowest level squares. Each region represents a cluster. One of the vehicles in that region is elected as location server. Every vehicle in that region updates its position to its associated location server. Each location server sends the aggregated location information to a higher-level server.

In the second approach, a road is divided into fixed segments [32–34] as shown in the Fig. 4. Group of the vehicles in that segment forms a cluster. Every vehicle in that cluster sends its location to the CH. CH sends locations to a higher-level location server which can be an RSU or a moving vehicle.

Static clustering has some advantages such as reduced computation complexity and low signaling cost during CH election. However, dependence on a fixed point to select a CH results in frequent changes in CHs [29].

In dynamic cluster-based location service [35–37], vehicles having similar characteristics form one cluster and move within clusters. In dynamic clustering, vehicles move with clusters, as shown in Fig. 5. There may be more than one cluster in neighbouring area. Dynamic clustering is more flexible. Referring to Table 1, all the presented location service schemes are compared in terms of characteristics, infrastructure, scalability, overhead, high density and speed respectively. Moreover, analysis in terms of pros and cons is highlighted in Table 2.

3 A critical analysis of cluster-based location service schemes

In the cluster-based location service, a CH plays the role of a location server. Every CM sends its current position to its associated CH. The CH maintains the location information of its CMs. It also sends the aggregated location information of its CMs to a higher-level server which may be another vehicle or RSU. Whenever a vehicle needs the position of another vehicle, it generates a query to its CH, the CH looks up the position of the requested vehicle in its location table. If the CH has the location information, it responds back to the source vehicle otherwise it will forward the request to a higher-level server. If the higher-level server has the position information in its database, it will respond back to the requesting CH, otherwise it fulfils the query by contacting other neighbouring servers [16]. The performance of the cluster-based location service depends

Table 1 Analysis of location service schemes

Location service schemes	Flat	Quorum-based	Hierarchical (Static clustering)	Hierarchical (Dynamic clustering)
Main characteristics	Flooding	Quorums	Geographical area/RSU based	Mobility parameters
Infrastructure assisted	No	No	Yes	Both
Scalability	Low	Low	High	High
Overhead	High	Average	Average	Low
Performance (in high density)	Low	Average	Average	High
Performance (in high speed)	Low	Average	Low	High

Table 2 Location service schemes pros and cons

Location service schemes	Pros	Cons
Flat	Simple, less computation complexity, no infrastructure cost	Flooding overhead, congestion, increases delay, increased localization error, low throughput
Quorum-based	Location updates and query mechanisms are simple, no infrastructure cost	Quorum formation is complex, increased localization error Quorum boundary issue
Hierarchical (Static clustering)	Cluster formation simple, less overhead	Although cluster formation overhead is less but high overhead due to frequent CH changes, infrastructure cost
Hierarchical (Dynamic clustering)	Mobility vehicles moves clusters, flexible, with clusters, flexible, enhanced stability	Cluster formation and maintenance overhead, infrastructure cost

Table 3 Analysis of cluster-based location service schemes

Scheme	LS election parameters	Dynamicity	Infrastructure based	Overhead	Link reliability	Scalability	CH instability
EMBLS [16]	High density intersections	Static	No	High	Average	Average	High
ECBLS [31]	Center of the region	Static	Yes	Average	Low	Average	high
HMBLS [21]	Lowest speed and high density	Static	No	High	Average	Low	high
ARTMS [32]	distance from the center	Static	Yes	High	Low	Low	frequent
HCBLS [33]	Distance from the center	Static	Yes	Average	Low	Average	high
VALS [34]	Distance from the center	Static	No	Average	Low	Low	high
ULS [38]	RSU range	Static	Yes	High	Average	Average	average
CCLS [39]	RSU range	Static	Yes	Average	Average	Average	average
MGLSM [35]	Direction, center of the group	Dynamic	Yes	High	Low	Low	average
CBLS [36]	Distance, speed, direction and neighbours	Dynamic	No	High	Low	Average	average
MoGLS [37]	N/A	Dynamic	Yes	High	Average	Average	N/A

on several factors such as stability of CH, CMs, effective maintenance mechanisms, distribution of location servers, location update mechanisms and location query mechanisms. The critical analysis of the cluster-based location service, which includes static and dynamic clustering, is given in the following section and highlighted in Table 3.

3.1 Location service based on static clustering

In the static clustering, the area is divided into different segments and the collection of vehicles in each segment defines a cluster. A CH is elected based on the position of vehicle in that segment. All other vehicles are the CMs in this segment. The size of the segment varies according to the application. A new CH is defined for each segment. A critical analysis of the location service schemes based on static clustering is given in the following section. An Efficient Map Based Location Service (EMBLS) [16] is a two level hierarchical service in which the whole city is divided into four squares. At first level, within each square, Intersection Leaders (IL) are identified at different intersections based on the vehicular density at that intersection. All those vehicles that are within half the range (0.5R|R: Radio range) from the center of the intersections are selected as IL. Each vehicle sends its location information to the nearest IL. At second level, Location servers are identified approximately at the center of the city based on high density intersections. All vehicles that are within half the range of R, are named as location servers. All vehicles update their location to IL and IL sends aggregate information to location servers using greedy perimeter stateless routing. Redundancy is reduced by sending aggregated updates and load is distributed due to using large number of ILs and location servers. However, location servers are defined without considering mobility parameters which shorten the lifetime of location servers. Location servers at both levels are moving vehicles which increases server instability and many vehicles might lose their association with certain ILs due to their varying speed. For all those vehicles moving in a different direction with respect to IL, the distance between vehicles and ILs increases. This results in low success ratio of position updates and queries.

In Efficient Cost-Based (ECB) location service scheme proposed by [31], a map is distributed into two levels. Nine level-1 grids are clustered into level-2 grids. Each level-2 grid consists of a location server. It acts as a location server for local vehicles and dedicated location server for a subset of remaining vehicles. Cost functions are defined to evaluate the cost of location update and query. Location servers are elected from areas based on the cost functions. Location update cost in ECB is less than EMBLS because it only requires to update the location information to local and dedicated location servers. Local vehicles can easily update their information to location servers, but it is very difficult for the vehicles which are away from the dedicated servers to update their position. Location servers are elected without considering mobility parameters which creates location server's instability. Furthermore, when location servers enter or leave the current area, handover issues are created. Even more to this, an extra communication overhead is created which degrades the performance of the location service.

Moreover, the Hierarchical Map based Location Service [21] is a bi-level hierarchical service in which city is divided into four level-2 squares, and each level-2 square is divided into four level-1 squares. Responsible Servers (RS) and Responsible Leaders (RL) are selected at the centers of level-2 squares using minimum speed and high-density parameters. RS and RL election metric weight is calculated into two steps. In the first step, every vehicle computes average intersection density (as a sum of all the waypoints' densities in a square). In the second step, vehicles with minimum speed are searched out. Then, minimum speed vehicles with high density intersections, that lies (1/2)R communication range as shown in the Fig. 6, will be candidate for RL/RS. Each vehicle sends its location information to RL when it enters the corresponding square. Before moving away from their responsible area,

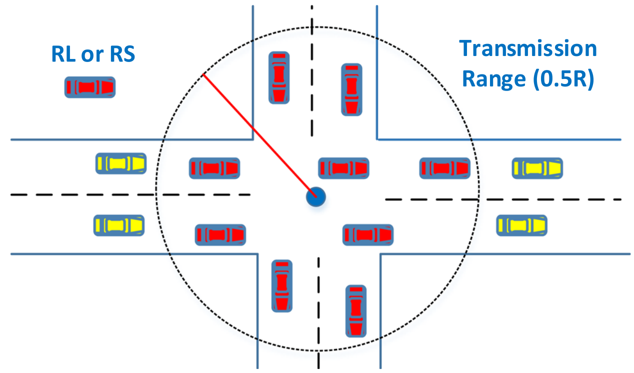

Fig. 6 Selection of responsible leaders and servers [21]

each RL/RS hands over the database information to new RL/RS having minimum distance. Above mentioned scheme has improved EMBLS by adding minimum speed metric along with high density intersection to improve lifetime of RL and RS. It has also reduced the location update delay by adding two levels hierarchy. Extra signaling overhead still exists due handover process. In addition to this, minimum spanning tree is mentioned without describing location forwarding process to reduce the update delay.

A real time traffic monitoring system is proposed by [32] that is based on the use of RSUs. A road is divided into fixed size units, where each unit defines a cluster. The vehicle nearest to the unit center is automatically elected as a CH. Every vehicle maintains a location table which includes the vehicle ID, position, speed and direction. Every vehicle shares this information with the CH periodically. To keep up to date view of the vehicles on the road, CH updates this information to its nearest RSU. The performance of the monitoring system depends on the fixed size of the units. Each CH has its default communication range. The positions of only those vehicles will be updated which are within the range of CH. Location information of those vehicles which are within the cluster but outside range of CH will not be updated to the CH. CH is elected without considering mobility parameters due to which cluster instability increases. This factor will degrade the performance of the monitoring system that is based on the location service.

A Hierarchical Cluster-Based Location Service in Urban Environment [33] comprises of three levels hierarchy. The lowest level is the cluster. Each CH updates information about vehicles to its nearest RSU and RSU sends updates to regional location server. In this scheme, road is divided into segments. The vehicle nearest to the center of the segment at any instant will be elected as CH. Being CH, it will send location information of all vehicles present in that segment to the nearest RSU. RSU are used to store the location information which will not only decrease updating cost but also improve the location server's stability. When a CH is not in the transmission range of an RSU, then in this scenario the CH depends on an intermediate vehicle to send location updates to the RSU. The nearest vehicle to the RSU is elected as forwarder. Thus the CH sends location updates to this forwarder and then the forwarder delivers the location information to the RSU. Nearest device is used to forward the location information. In this situation, the distance between CH and forwarding device will increase which results in messages packet loss and poor quality. Location Information of each vehicle is updated at three levels which incurs extra updating overhead. Although researchers tried to elect CHs without any extra signaling cost during CH election, but that resulted in CH election chain. Every vehicle which is passing by the segment center has equal chance of being elected as a CH. After election, every CH sends broadcast messages to collect the location information of the vehicles in the segment, and an extra communication overhead is created. Besides this, CHs are changing frequently, due to which location of some vehicles is not updated to the server. Extra communication overhead does not only affect the performance of the location service in terms of location query and localization errors but also disturbs other applications on the network. In [34], the author has tried to resolve the issue of lack of RSUs by using vehicles nearest to the intersections as RSU. At the intersections, where RSUs are not available, one of nearest vehicle to the intersection is elected to perform the functions of an RSU. The vehicle with the lowest speed within a defined radius is elected as an RSU. Typically, in normal CH-CM scenario, every CM sends its location information to its respective CH. The CH updates these locations to an RSU but in this intersection scenario, the CH will send location information to one of its CM which is not stable as compared to the CH.

An RSU designation is based on lowest speed, and fast speed CHs will bypass quickly without handing over location information of its CMs. Due to traffic from different directions, more than one vehicle claims as RSU, which will create communication overhead around the intersection. High density will also affect the election of vehicle as RSU. Although study has tried to reduce RSU deployment cost, but dependency on the instable vehicle will affect the location update and location query requests, which ultimately will degrade the performance of the location service. The election of the CH is bounded to the fixed point without considering mobility parameters of the vehicle, whereas speed and density also vary in each segment. So, the process of clustering is instantaneous and cluster instability does not only incur deployment cost, but dependency on the instable vehicle will also affect the location update and location query requests, which ultimately will degrade the performance of the location service.

Moreover, in the following studies, RSUs are directly used to define static clusters. In the proposed scheme [38] routing is integrated with location service. RSUs are used as location servers. All RSUs are connected with each other. Each RSU does not only provide the location of the target vehicle, but also provides the best path from source to destination. Congestion is reduced by assigning penalty cost to the selected roads. The focus of this study is to optimize the routing by reducing congestion. The performance of the location service is affected due to depending completely on RSUs. In order to find the location, the RSU interconnect with each other, without any central location server. Due to which, communication overhead and location query delay increase. The hybrid scheme [39] exploits RSUs as location servers. A cluster is formed within the range of RSU. Every vehicle in the range of an RSU updates its location to that RSU. The proposed work reduces the cluster formation overhead and signaling cost by designating RSU as location server and integrating location service and routing functions respectively. However, when RSUs are deployed at the intersections, every vehicle within the range of an RSU will update its location to an RSU and create congestions. Besides, positions of those vehicles which are not in the range of RSU will not be updated to RSU due to which the delay and query success rate are affected.

3.1.1 Issues pertaining to location service based on static clustering

The static cluster-based location service schemes consider the area division approach to make the clusters. Vehicles in each division form a cluster. Static clustering has some advantages such as simplicity of cluster formation. CHs are elected without any extra signaling cost and complexity. Every CH is only responsible for its designated area. Regarding disadvantages, CH election depends on specific locations such as high-density intersections. These schemes did not ensure the proximity between location servers and vehicles. The position of those vehicles which are outside the range of location server is not updated. The ratio of isolated vehicles increases on the network. Location servers are elected without completely considering mobility parameters. When these location servers leave their respective areas, new location servers are defined. Due to this, location server election process occurs frequently which affects the performance of the location service. Update and query packets seem to be forwarded several times to the location servers at level-2 and level-3. These servers may be on the other side of the area, as a result, extra overhead of message forwarding will be created. Likewise, frequent handover occurs when location server moves between different areas. Moreover, when these servers move out of their designated areas, the hierarchies of location servers change. The location queries related to these servers are forwarded to the next higher-level servers which increases overhead and delay until the reformation of the new location servers is finalized.

In the static cluster–based location schemes, CMs have to affiliate with a new CH in each cluster due to cluster-

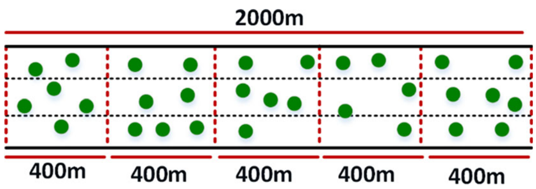

Fig. 7 Static clusters

ing boundary limits. These CMs affiliations are not based on mobility parameters, instead they rely on bounded cluster region. The vehicles whose speed is not similar to the CH will change clusters frequently. This factor affects the flexibility of clustering process. Static clustering is based on fixed segments. CHs have to depend on intermediate servers to update the locations to higher level server. One of the important factors while forming static clusters based on area is the size of the region. There is a need to optimize the area while considering the transmission range of vehicles. For example, if cluster size is defined with lengths 200 m and 400 m, overlapping areas will be created. On the other hand, if clusters are of higher sizes such as 600, 800 and 1200, mostly vehicles will not be able to connect to CHs. Also in static clustering, five clusters are required to cover 2000 m road by taking cluster size 400 m. Vehicles will have to change five clusters as shown in Fig. 7.

So, CH and CM change frequently. Due to the abovementioned issues, message loss, location update and query delay, query failure rate and communication overhead increase which affects the performance of the location service.

3.2 Location service based on dynamic clustering

In the dynamic clustering, clusters are formed by nodes moving in the same direction and have similar characteristics such as speed and distance between vehicles. CH is elected from vehicles having optimum mobility parameters. CM affiliates with the existing cluster based on CH trajectory. Figure 8 describes the conceptual view of location service based on dynamic clustering. The following section critically analyzed the location service based on dynamic clustering. In [35], the authors have focused on improving the performance of the location service by reducing the communication overhead and increasing the location query accuracy. Their scheme is based on two levels of hierarchy. In the lowest level, a Group Head (GH) collects the location information of its Group Members (GM) and sends this information to a fixed higher-level Regional Head (RH). The RH performs two main functions: store the location information of all vehicles that is sent by GHs in its region and respond to the location queries of member vehicles forwarded by GHs. Vehicles are grouped based on distance, speed and direction parameters. To advertise itself, a GH broadcasts GH-advertisement messages periodically and vehicles register through GH-registration messages. To communicate with RH, a GH uses four types of messages: RH-registration, RH-location-update, RH-membership-update and RH-deregistration. In the dynamic group management process, every vehicle makes the decision of joining a group by observing its benefit in terms of the sojourn time, which depends on distance and speed of the vehicle and GHs as shown in Fig. 9. Every GH (Group Head) maintains the location information of its GMs (Group Members) and also sends a copy to a centrally located RH (Regional Head) for further storage. The GM that needs the location of another vehicle, sends a request to its respective GH. If the GH has the location information of requested vehicle, it will respond back with the location information. Otherwise, GH forwards this request to a higher-level RH. After fulfilling the query, the RH responds to the GH request. Then the GH responds back to its GM.

Although the study has tried to improve the performance of the location service but there are still some limitations in terms of the communication overhead created during the calculation of the expected sojourn time. In addition, the sojourn time is calculated based on the instantaneous values of distance and speed of the vehicle and GH without considering optimum values. Moreover, the performance of the scheme degrades in high speed and denser areas. Region based location service [36] uses moving vehicles as location servers to increase the scalability and efficiency of the location service while reducing the capital cost that is required for the deployment of the fixed infrastructure. The proposed solution divides the whole city into four regions and uses three levels of hierarchy. In the lowest level, CHs are selected using distance, speed, direction and number of neighbours' parameters. At the next level IS (Intermediate Servers) are selected based on least speed and distance from the intersection, also, these ISs are selected at the intersection where density is higher than average. The vehicles that are nearest to the city centre at congested intersections are used as main servers. Two algorithms are proposed: the first describes the clustering process and the second optimizes the location query. Researchers have tried to improve the scalability and efficiency using moving vehicles as location servers. When the distance between CH, IS and MS increases beyond the communication range, location updates and location query requests will be affected. Location server election process is focused near the intersection particularly at high density intersections which indicates that the proposed solution might not work in sparse network environment. As position-based applications entirely depend on the underlying location service, some sort of fixed infrastructure is highly necessary to store the locations of the vehicles. Cluster instability increases due to including moving vehicles as location servers at three levels of the proposed scheme. Moreover, extra communication overhead will be created. In result, the

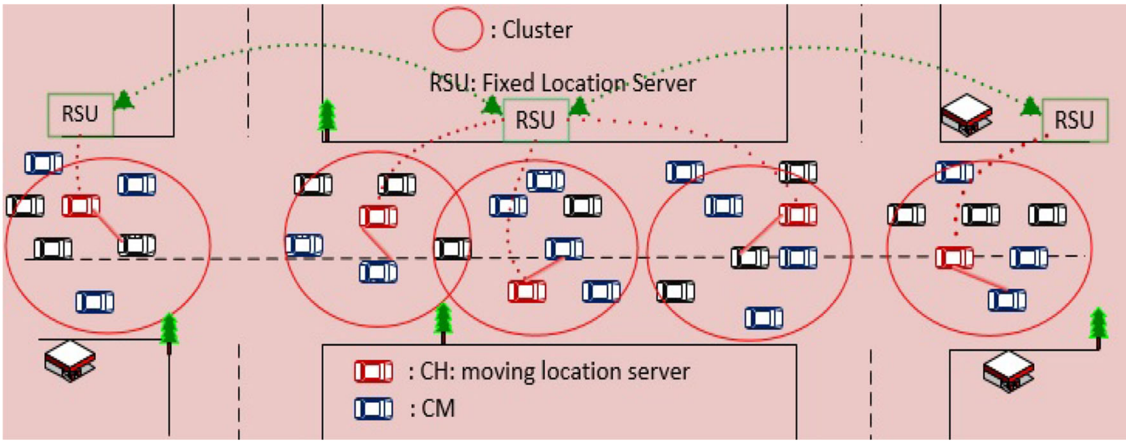

Fig. 8 Dynamic clustering-based location service

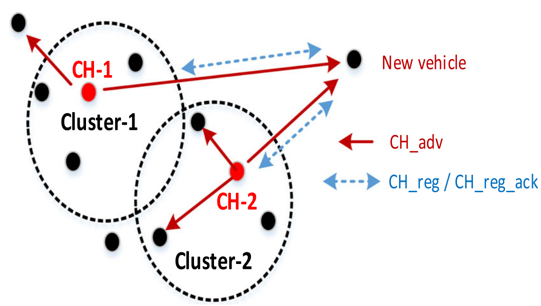

Fig. 9 Cluster Member affiliations [35]

performance of the location service will also be affected due to entirely depending on moving location servers.

The Mobile Group-based Location Service (MoGLS) scheme proposed by [37], addresses the issues of signalling overhead and reliability by using two levels of hierarchy. In the lower level, dynamic groups are formed based on similar trajectory, in which one vehicle performs the functions of Group Leader (GL). GL collects the locations of its GM. GL sends aggregate and relative location updates to higher level fixed location servers, which store the locations of vehicles for further access. Reliability is achieved through the logic that GL is moving with its GMs. A group merging algorithm is used to increase the efficiency of the location service. The study has tried to simplify the cluster member affiliation criteria by using the euclidean distance between vehicle and the GL. However, sojourn time calculation is not based on optimum limits of the speed due to which the vehicle and the GL soon would become out of the range, and the vehicle will again continue its search for another GL. Regarding GL election, any vehicle that is not receiving messages from neighbouring GL up to a certain time, will elect itself as GL and sends GL broadcast messages over the network, which increases communication overhead. As a result, in denser part, the performance of the proposed scheme will be affected.

3.2.1 Issues pertaining to location service based on dynamic clustering

A large number of existing applications such as routing, channel access management, information dissemination and security use the dynamic approach due to its advantages such as stability, flexibility and reliability as compared to static clustering. One of the important characteristics of dynamic clustering is that vehicles move with its CH. Vehicles having similar characteristics form one cluster. There may be more than one cluster in a neighboring area. The performance of the cluster-based location service particularly depends on the stability of the cluster. Although existing studies have tried to improve the stability of the CH, there is a need to improve the stability of the CH while considering the location service requirements. A CM is the vehicle whose position is being maintained. Stability of a CM in a cluster is a key requirement to improve the performance of the location service. Frequent change of the CMs creates CM affiliation overhead and degrades the performance of the location service. Moreover, due to the limitations of CM affiliations mechanisms, some vehicles remain isolated and may not be able to join any cluster. Their position is not updated to any CH, due to which location query success rate decreases. Furthermore, another important requirement for the cluster-based location service is the continuous cluster maintenance. There is a need to improve the maintenance schemes such as cluster merging, cluster splitting and CM leaving mechanisms in the context of location service requirement. In the dynamic cluster-based location service, every CH collects vehicle location information and update to a higher-level server which may be an RSU or a vehicle. Existing studies have tried to enhance the location update mechanisms but still there is a need to optimise

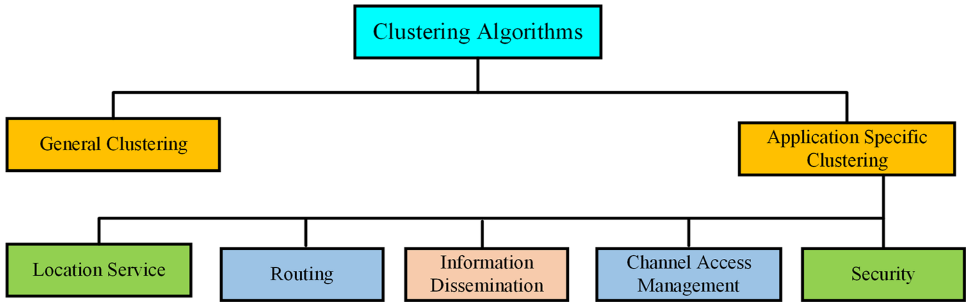

Fig. 10 Classification of clustering algorithms

the location update mechanism and location query mechanisms.

In the dynamic cluster-based location service, the most stable vehicle from a group of vehicles is elected as a CH. The stability of the CH depends on the election criteria. Cluster stability is obtained at the cost of cluster formation overhead. In the dynamic cluster-based location service, flexibility is obtained through automating the process of CM joining, leaving and cluster merging. When there are more than one clusters in neighbouring area cluster merging takes place. When cluster moves with its members, it reduces the usage of intermediate links to update the data to a higher-level server. Every CM communicates with other nodes in the network through its respective CH, which reduces the communication overhead and increases the scalability. Although, dynamic clustering is more flexible and scalable, but still there is a need to enhance the cluster stability by improving the CH election criteria, the CM affiliations mechanisms and adaptive cluster maintenance schemes.

4 A critical analysis of clustering schemes in several cluster-based applications

This section investigates the characteristics of several types of clustering schemes and how suitable they are to serve cluster-based location service. Figure 10 classifies clustering techniques based on their applications. A large number of clustering algorithms for general and application specific purposes have been proposed in VANETs literature. The following is a discussion of the general clustering and the application-based clustering algorithms and their efficiency in serving the cluster-based location service.

4.1 General clustering

The general clustering algorithms are designed without considering the requirements of any specific application. The overall objectives of these algorithms are to increase the stability of the clusters. Most of the existing work attempted to improve the cluster stability by improving the CH election criteria. The ultimate objective is to increase the CH lifetime. The CH election revolves around optimizing the distance between CH and CMs, the CH speed, the CH direction and the cluster density parameters. However, currently, less work has been done in other aspects of the clustering such as CM affiliations and cluster maintenance [27, 40–49]. Artificial intelligence based study [50] uses Genetic Algorithm (GA) and Tabu Search (TA) to enhance the performance of weighted K-Mediod algorithm by improving cluster maintenance phase. In the new proposed model, border nodes affiliations are optimized by integrating GA and TS. In the general clustering, all resources such as bandwidth and channel access are fully utilized to maximize the stability of the clusters. CH election mechanisms are optimized without considering the requirements of other applications. Therefore, stability of the cluster is affected when these algorithms are used in location service. The location service has its own working mechanism where CH has to perform clustering functions as well as location service. So, there is a need to design clustering algorithms that can consider the application requirements.

4.2 Application specific clustering

4.2.1 Location service

Location service is utilized to store the current locations of all vehicles in VANETs. Each vehicle depends on a location service to get an up-to-date position of another vehicle. In the cluster-based location service, the CH collects the location information of its CMs, updates these locations to higher-level sever and responds different queries related to location. The performance of the cluster-based location service depends on the stability of the CH, CH and robust maintenance mechanisms. Cluster-based location service has its own working mechanism where a CH has to perform clustering functions as well as location service. So, there is a need to design clustering algorithms that can fulfill the requirement of both location service and cluster creation/maintenance.

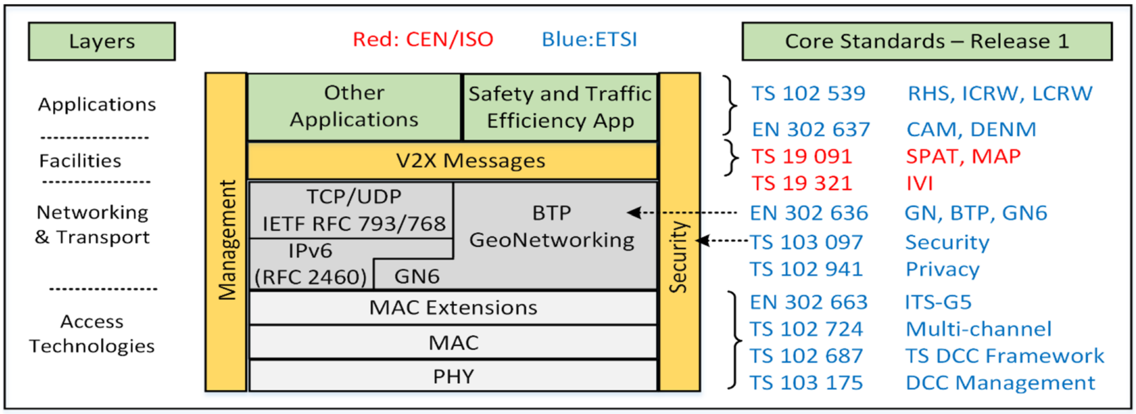

Fig. 11 Protocol stack and related core standards for C-ITS in Europe [55]

4.2.2 Routing

The VANETs routing protocols can be divided into two main types which are topology based and position-based routing. Topology based routing protocols use links information to forward the packets from a source vehicle to a destination vehicle. Position-based routing protocols use vehicle's current location. The performance of the position-based routing protocols depends on the location service that is being used [51, 52].

Communication among vehicles, and between vehicles and roadside infrastructure is considered as a base technology to improve the performance of VANET-base applications. Two different standards have been developed to provide the communication. In Europe, a standard was emerged as cooperative Intelligent Transportation systems (C-ITS) that is based on ITS-G5. In the US, IEEE 802.11P evolved an equivalent standard to C-ITS. Figure 11 gives an overview of protocol stack of C-ITS Europe standard. The C-ITS standards follow a general architecture, specified in ETSI EN 302 665 and ISO 21217.

The access technologies depend on ITS-G5 to provide physical and MAC layer functionalities. G5 refers 5 GHz frequency band. In the ITS-G5 standard, spectrum is divided into four types which include ITS-G5A, ITS-G5B, ITS-G5C and ITS-G5D as shown in the Fig. 12. ITS-G5A depends on 30 MHz band to provide safety and traffic efficiency applications. ITS-G5B uses 20 MHz to provide non-safety services. ITS-G5C shares RLAN band and ITS-G5D is saved for future research.

On the networking and transport layer, GeoNetworking provides ad hoc communication using geo-addressing over ITS-G5. GeoNetworking depends on geographical location to provide single hop and multihop communication in VANETs. GeoNetworking uses various packet handling modes to provide different types of communication which includes geo-unicast, geo-broadcast, geo-anycast,

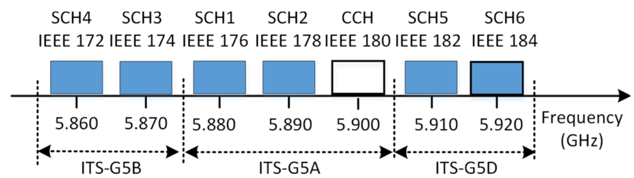

Fig. 12 IEEE 802.11P ITS-G5 channel frequency band [55]

single-hop-broadcast and topologically-scoped-broadcast. IPv6 packets can also be transmitted over GeoNetworking using adaptation sublayer GN6 [53–55].

To find the location of the destination, source node uses location service and broadcasts location requests to the intermediate nodes until it reaches the destination. The destination node replies with a geo-unicast packet [56].

Clustering plays a vital role in position based routing packets through forming a hierarchy structure over the existing adhoc network. The use of clustering in routing protocol minimizes flooding and reduces interfacing between vehicles and area in which messages are sent. The scalability of the routing protocols is increased through the use of clustering. In the majority of the cluster-based routing protocols, CH performs the inter-cluster communication.

Moreover, CMs are used to relay the message [57–64]. The hybrid Scatter Tabu Search (HSTS) approach is proposed to address the CM affiliation problem [65]. Based on this algorithm, vehicles affiliate with best suitable CH to enhance the performance of different applications. Moreover, a scheme is proposed to improve the cluster stability by enhancing k-medoid clustering algorithm [66]. Number of clusters and CHs are elected based on the size of environment and transmission range. CM affiliations depend on direction, relative speed and proximity. A new parameter i.e. disconnection frequency is introduced for the CH election. When clustering is used for the purpose of routing, the concern is to create clusters that that are stable enough to deliver the messages from the source to the destination. However, in location service systems, CHs play the role of location information servers which means that it is very crucial to keep the clusters stable for longer period of time. In addition, most of the cluster-based routing protocols do not take into consideration the effect of routing overhead and network traffic on the performance of cluster-based location service systems. For the aforementioned reasons, it can be concluded that the clustering algorithms designed for routing protocols are not convenient for location service systems. Therefore, to use location services for position based routing, it is necessary to consider the requirements and the consequences of both the routing process and the location service while designing the clustering algorithms.

4.2.3 Information dissemination

Another usage of the clustering approach is to disseminate the information in VANETs. A message is broadcasted using clusters. Upon receiving a message, The CH disseminates the information to its CMs and also communicates with other clusters to exchange messages.

Clustering is used to reduce the number of messages transmitted through the networks. When an event takes place, the CM notifies its associate CH. To enhance the credibility of the received notification about the event, the CH confirms the received notification by receiving more notifications from other neighboring vehicles about the same event. In some approaches, CMs participate in the message dissemination process as well. Moreover, the multihop approach is used to disseminate the message in some studies [67–74]. The Kinetic theory-based relay node selection scheme is proposed to improve the performance of the message dissemination by mobility prediction approach [75] in which the kinetic degree of a node is estimated by predicting its future position and velocity. Best relay node has optimum value obtained through the combination of the three variables such as Coverage Kinetic Degree (CKD), Kinetic Distance to Mean (KDTM) and Signal Power (PW).

The proposed scheme reduces the redundancy and delay while improving the reliability of the disseminated messages. The purpose of using clusters for message dissemination is to reduce the flooding effect and to spread the message over a large scale. On the other hand, in location service systems, CHs collect the location information then forward it to the infrastructure servers. In contrast to clustering for information dissemination, location service clustering does not focus on delivering the message to all the vehicles, rather its concern is to collect the location information from all the vehicles in a timely manner. Therefore, clustering for information dissemination focuses on the scalability and network congestion issues, while location service clustering focuses on the vehicles mobility issues and how to keep track of the vehicles locations. Therefore, it is highly unlikely that the clustering algorithms designed for information dissemination can satisfy the requirements of location service.

4.2.4 Channel access management

Another advantage of using clustering is its role in supporting channel access management in the Media Access Control [76] layer. Basically, the CH can allocate the bandwidth for its CMs on the basis of some criteria, hence improves the Quality of Service (QOS) and increases reliability by reducing collisions. IEEE 802.11 uses the RTS/CTS technique to avoid collisions. This technique is not applicable for broadcast communication, where messages have to be sent to many vehicles [77]. IEEE802.11p uses CSMA/CA to give channel access to different nodes on the network. Due to contention and hidden nodes, vehicles have to wait to get access to network resources. Also the performance of CSMA/CA decreases when network load and node density increases [78]. Time Division Multiple Access (TDMA) based methodology depends on time allocation, in which the CH assigns timeslots to its CMs. This methodology replaces the CSMA/CA technique, which suffers from the hidden node problem [78–85]. In the channel access management, the main task of the CH is to assign channels to its cluster members according to the requirements of the applications. The ultimate objective of the MAC based clustering is to make efficient use of bandwidth and to avoid collisions. However, location service clusters are quite different in two perspectives. First, they work in the upper layers of the network stack. Second, the location service clusters aim to maximize their stability by focusing on vehicles mobility parameters. It is obvious that clustering for the purpose of channel management does not consider into account the requirements of location service systems.

4.2.5 Security

In VANETs, vehicles are exposed to different kinds of threats. Different services and mechanisms such as confidentiality, authentication, and integrity are applied to secure the network. Clustering approach is also playing a significant role to secure the network. While electing a CH, apart from usual distance and speed parameters, security variables like trust level is also included. Vehicles are continuously monitored to maintain trust level of the network. The CH observes the credibility of the message by sending messages to the neighbor vehicles. Decentralized key management is implemented through the CHs. Vehicles are registered to a Certificate Authority (CA) that holds the data related to vehicles such as vehicles ID, encryption and decryption keys [86–93]. Table 4 provides a comparison of the application specific clustering techniques. The majority of the security-based clustering schemes revolves around the security of the CH and CMs.

Table 4 Analysis of application specific clustering algorithms

Application	Main objective	Hoping	Message overhead	Performance metrics
General Clustering	To improve the stability of the cluster	Single, multi	Low	Average CH lifetime, average CM lifetime, CH change number, clustering overhead
Routing	To improve the route stability	Single, multi	Average	PDR, end-to-end delay, throughput and cluster stability.
Channel access management	To assign channels to make efficient use of bandwidth and to avoid collisions	Singe	Low	Packet delivery ratio (PDR), transmission delay, throughput, packet dropping rate, cluster stability
Information dissemination	To disseminate the information with maximum coverage and minimum delay	Single, multi	High	Transmission delay, packet delivery ratio (PDR), coverage area, cluster stability
Security	To secure the information	Single, multi	Average	Authentication delay, overhead, accuracy, attack detection rate
Location service	To provide the location information	Single	High	Average CH, CM lifetime, signaling overhead, delay, query success rate, localization error, fraction of vehicles saved in the location servers

Major focus is on the trust worthiness of the CH and CMs, and distribution of private and public keys to secure the communication between CH and CMs. Whereas location service-based clustering emphasizes on the stability of the CH and CMs while neglecting security aspect requirements, however, it is very important to provide trusted location information and to protect vehicles location information from any attacks. Therefore, both the security and the stability of clusters requirements are necessary to be considered as a future work in clustering for location service systems.

4.3 Discussions

It can be observed from the above discussion that the clustering schemes proposed for each application work differently in order to optimize the performance of the application. However, the performance of such schemes may not be desirable when applied in a different application scenario. General clustering schemes are designed without considering any particular application requirements. Routing highly depends on the stability of the routes by using CHs as intermediate nodes. CHs take forwarding decisions based on predefined parameters. In some schemes, CM may also relay the messages from one cluster to another. In addition to this, a CH performs cluster management functions to keep the cluster alive. The major function of the CH in channel access management is assigning channels while considering parameters such as data priority, bandwidth and number of channels. Each CM directly communicates with its CH to get resources. Information dissemination schemes depend on the clustering approach to send the information to a maximum number of vehicles in a minimum time while controlling the flooding and network overhead. Security schemes use clustering to secure VANETs networks through authenticating vehicles. It is obvious that general clustering and application specific clustering are not suitable for location services. Recent study [20] proposed that location service protocols must exhibit certain characteristics such as robustness, load balancing and locality awareness. Based on the aforementioned investigation and discussion, we extended the characteristics of cluster-based location service to include the presented list in Table 5.

5 Challenges and future directions

- *Clustering instability*: The uttermost requirement of a location service is the stability of CH and CM. CH is the vehicle which keeps and updates the location of CMs. If the CH is changing frequently, the functions of the location service will be affected severely. The CMs are the vehicles with their location being maintained. The frequent joining and leaving of the CMs result in degrading the performance and accuracy of the location service. Although many studies have been performed to optimize the stability of clustering, there is still a room for improvement to address the rapid topological changes of the VANETs network.
- *Intelligent clustering*: Since vehicles mobility are predictable to a certain level, clustering in VANETs can be improved through artificial intelligent mechanisms. In location service systems, the CHs are the nodes that gather information about the CMs' mobility. Thus, CHs already have a large amount of information to be used intelligently to predict vehicles' positions and adapt clustering accordingly.

Table 5 Location service specific characteristics

Characteristics	
Cluster stability	In the cluster based location, at lower level, CH collects and maintains the locations of its CMs. Performance of the location service highly depends on the stability of the clusters
Minimum isolated nodes	Isolated or Undecided Nodes (UN) are those nodes which could not be affiliated to any cluster due to CH or CM affiliation criteria. Moving nodes are the key entities whose position is maintained in location service. In order to enhance the performance of location service, there should be minimum isolated nodes in the whole network
Efficiency	The performance of the location service depends on location update and location query mechanisms. Overhead of location updates and location queries should be kept minimum to improve the efficiency of the location service
Robustness	Location service utilizes location server to maintain locations. Location service should not be disrupted due to failure or disconnection of these server from network
Load balancing	Location service should utilize load balancing techniques to avoid congestions in the network
Locality awareness	Distance between location server and querying source should be less than the distance between source and destination. Location query packets should not be propagated unnecessarily over the whole network
Accuracy	Location service should provide accurate and up-to-date location of nodes in the network
Scalability	When the number of nodes in network increases, the performance of the location service should be sustained by maintaining above characteristics

- *Fault-tolerance CH*: The main key player in cluster-based approach is the CH. The CH keeps the records of current positions of its CMs and also sends location updates to higher level servers for further usage. Due to sudden failure of the CH, the location service in its cluster will collapse. So fault tolerance mechanisms are required to back up the functions of the CH and to prevent any disruptions in the location service system.
- *Dynamic CH load distribution*: In urban areas, normally, the vehicular network is congested due to the large number of vehicles. This does not only increase the number of messages, but also increase communication overload on the respective CHs. Therefore, mechanisms are required to adjust the load of CHs dynamically.
- *Optimum hierarchical level location updates*: Clustering based location service depends on a hierarchical approach in which every CH updates the fresh locations of vehicles to its higher level servers. Optimum location update mechanisms are required which can provide accurate and timely location updates while using minimum resources.
- *Efficient location query mechanisms*: Every vehicle that needs the location of another vehicle sends a query to its CH. If the CH has the information of the requested vehicle, it will respond back. On the contrary, if the CH does not have the information of the requested vehicle, it will respond after getting the location from higher level servers. However, locations of the source and target vehicles change suddenly and rapidly. Therefore, it is necessary to improve the existing location query mechanisms in order to provide accurate and timely location services while considering the hierarchal structure of the cluster-based location service systems.
- *Efficient communication channel access management*: In cluster-based location service, two applications namely cluster management and location service are running simultaneously. The CH collects the locations of its CMs, sends updates to higher level servers, responds to queries of its CMs. CMs send locations updates periodically to CH and also sends their queries to their CH. The co-existence of two applications results in communication collisions and congestion. Although many studies proposed general solutions for managing channel access, it is highly required to provide a channel access management solution which is specially designed to consider the functionality of the CH and the CMs in cluster-based location service system.
- *Reduced messaging overhead*: In Cluster-based location service, different types of messaging are involved such as CH advertisement messages, CH acknowledgement messages, CM beacon messages, CH registration messages to higher level servers, CH De-registration from the parent higher level server messages and cluster management messages. Although existing studies tried to reduce the communication overhead created due to these messages, there is still a need to optimize the usage of these messages.
- *Cellular technologies usage*: Recently many researches have been proposed regarding the usage of cellular technologies such as Long Term Evolution (LTE) and 5G in VANETs. Apart from its advantages in terms of speed and latency, there are still a number of open challenges that need to be considered such as the high cost of 5G communication between the vehicles and the base stations, large number of handoffs, overloading of base stations, frequent and speedy topological changes and vehicular density variation. In LTE, base stations are designed and deployed while keeping the requirements of cellular networks. When these base stations are used in location service, following issues arise: (1) deployment of base stations as location servers in the context of the location service [94]. Cluster

formation challenges with reference to considering LTE connection parameters with vehicles and (2) interfacing challenges of lowest level servers (which are also called CHs) with base stations.

- *Hierarchical collision-free location server's communication*: In the cluster-based location service, some sort of the infrastructure such as RSU, high level servers are needed to store the location of the vehicles. Every CH connects to RSU to update the location of its CMs. Mechanisms are required for inter-cluster communication and CH to higher-level server communication to avoid collisions.
- *Efficient cluster merging*: Due to dynamic nature of the clustering, there is always a possibility of having more than one cluster in the neighboring area. The number of CMs in each cluster varies. Some clusters have fewer members as compared to others, but all clusters are sending control messages and utilizing network resources. It is a valuable work to provide a decision-making technique to evaluate the available clusters and decide when and which clusters to merge or split.
- *UAV as a mobile location server*: In the recent years, researchers have explored the usage of Unmanned Aerial Vehicles (UAVs) to assist VANETs in performing and monitoring different functions. A UAV may play the role of a moving location server by storing the current positions of the vehicles. The performance of the location service increases with the usage of mobile location servers that can provide wide coverage. However, there are yet numerous challenges such as interfacing, communications, connectivity, mobility in the implementation and integration of UAV-VANETs architecture.
- *Software Defined Networking (SDN)*: SDN has been evolved as a new research area in communication networks. Software Defined Networking (SDN) system, includes SDN controller, SDN wireless nodes and SDN RSUs. SDN attempts to disassociate the forwarding process of network packets (data plane) from the routing process. In VANETs, SDN can be utilized to solve several performance issues and challenges such as resource utilization, routing problems, heterogeneous interfacing and bandwidth optimization [95, 96]. In a location service, SDN can be used to reduce the overhead of network topology management. However, SDN attempts to centralize network control which may create bottlenecks and limit location service.
- *Machine learning techniques*: Machine learning depends on datasets to define rules by automatically analyzing the different types of datasets. These rules can be used to predict different outcomes. There is a wide range of machine learning techniques such as K-Nearest Neighbors, Support Vector Machine which are used to develop a generalization capability to predict the behavior of input data. In VANETs, machine learning is used for misbehavior detection, routing decisions, intrusion detections, data centers and parking information [97–99]. In the location service, machine learning techniques can be used to predict the locations of vehicles, traffic behavior, analysis of location service performance parameters and traffic behavior.
- *Cloud and fog computing*: To meet the demanding requirements of the future ITS, cloud computing and fog Computing are expected to be future candidate technologies for 5G VANETs. Cloud computing has been deployed in VANETs to fulfill the requirements of different applications and services such as data storage, computing capability and timely information about the traffic status. Role of fog computing is evolving due to some specific requirements such as location awareness, low latency of different applications and services. Fog computing depends on highly virtualized computing and communication facilities at the proximity of vehicles in VANETs [100–102]. Fog computing may play the role of lower level servers to cater the location service requirements towards the edge of the VANETs networks. Integration of the fog computing towards the edge of network will improve the performance of the location service by providing real time location service through minimizing location updates and location query delay. Cloud servers can be used as a regional location server to store the locations of vehicles. There is a need to consider different challenges with reference to scheduling of location updates from lower level servers, location query responses, accuracy and privacy of locations saved on location servers.

6 Conclusion

VANETs have gained attention due to its potential applications. Researchers have investigated vehicles' clustering differently for various applications. This review paper investigated clustering in the context of the location service requirements. Existing location service schemes have been categorized on the basis of different characteristics. A detailed discussion and comparison of cluster-based location service schemes have been provided while exploring static and dynamic clustering approaches.

Comparison and critical analysis of clustering in cluster-based location service with other cluster-based applications such as routing, information dissemination and channel access management have also been given. Various existing research challenges and future directions have been highlighted as well that are still needed to be considered while designing cluster-based location service schemes. The primary challenge is to enhance the performance of the cluster-based location service schemes while improving the performance of location servers, location update mechanisms, location query mechanisms along with increasing the cluster stability, which depends on the stability of the CH, the CM and effective maintenance mechanisms. This paper provides a road map to explore the location service schemes while considering clustering approaches.

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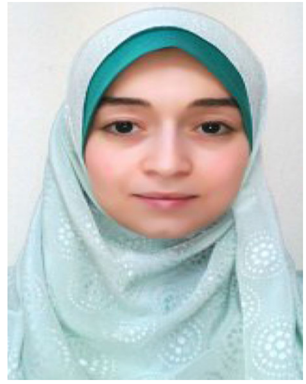

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