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A Cloud Computing Perspective for Distributed Routing in Vehicular Environments

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Abstract

Vehicular networks have been envisioned to provide us with numerous interesting services such as dissemination of real-time safety warnings and commercial advertisements via car-to-car communication. However, efficient routing is a research challenge due to the highly dynamic nature of these networks. Nevertheless, the availability of connections imposes additional constraint. Our earlier works in the area of efficient dissemination integrates the advantages of middleware operations with multicast routing to design a framework for distributed routing in vehicular networks. Cloud computing makes use of pools of physical computing resources to meet the requirements of such highly dynamic networks. The proposed solution in this paper applies the principles of cloud computing to our existing framework. The routing protocol works at the network layer for the formation of clouds in specific geographic regions. Simulation results present the efficiency of the model in terms of service discovery, download time and the queuing delay at the controller nodes.

Keywords

cloud computing; distributed routing; vehicular networks

1 Introduction

The efficient dissemination of emerging vehicular applications is a research challenge due to the highly dynamic nature of vehicular networks. The related research on distributed information management has gained much from academia and industry. However, efficient dissemination becomes demanding when information explosion overloads the network, consuming lots of network resources and thereby reducing network utilization. Our works proposed in [1]–[4] integrate the advantages of middleware operations with multicast routing to design a framework for distributed routing in vehicular networks. The application domain is designed using XML, with a content based subscription model used at the application level. Binary Decision Diagrams (BDDs) are used as a compact data format. The subscription attributes in BDD is converted to its equivalent ASCII code that forms the control packet for information routing. The multicast groups are formed using subscription clustering. At the network layer, the Spatio-Temporal Multicast Routing Protocol (SMRP) constructs a dynamic dissemination mesh overlay to forward the filter across the network to reach the interested subscribers. The framework uses three filtering methods including least constrained subscription filtering, subscription filtering, and advertisement based filtering.

The network is evaluated in terms of the efficiency to disseminate different classes of application messages using the three filtering methods. However, selecting a filtering technique depends on the type of application messages and the network scenario as well. For example, least constraint subscription filtering can be applied for safety messages while subscription or advertisement semantics can be used for other commercial application messages. Also in a considerably higher network density in a highway or a city based scenario, advertisement based routing can be more appropriate to reduce network overhead.

Nevertheless, routing in vehicular networks is a challenging task due to the mobility pattern and the availability of connection. Traditional vehicular networks are mostly established on pure ad hoc communications. Hence, inter-vehicle communication (IVC) is unreliable due to their high mobility. Moreover, the communication and computation capabilities of vehicles are constrained by the limited resources on their onboard devices. Besides, reduced delay, efficiency, scalability, reliability and security are very crucial for improving road safety and passenger comfort through intelligent transportation systems (ITS). A good routing framework should take all these for an optimized and dynamic decision.

On the other hand, the development of wireless communication technologies makes IVC systems heterogeneous. Thus it is envisioned that the vehicular network will eventually become a mobile extension of the internet.

Cloud computing [5] is a new computing model that makes use of pools of physical computing resources known as data centers. It uses virtualization technology in which a cloud physical resource can be carved up into logical or virtual resources as needed. This has changed the computation and communication mindset by decoupling computational assets from physical infrastructure. The main motive of cloud computing is exactly “what you need and when you need”. The proponents of vehicular cloud computing (VCC) aim to define a disciplined approach to the development, deployment and execution of the aforementioned services by harnessing the wealthy resources contributed by groups of vehicles in a transparent manner. This brings about an evolution similar to the shift from client-server applications on the internet to “classic” cloud computing [6].

In light of the above discussion, this paper proposes a distributed routing method based on the principles of the cloud computing. It follows a cloud model for VANETs with the virtualization of resources and services. In order to apply the working principles of cloud computing, we assume a stack of protocols for distributed routing and the virtualization of available resources to the network nodes. At the bottom of the stack, MAC and PHY layers use the IEEE 802.11p. The virtualization procedures are configured into a separate layer called the VNLayer. On top of this lies the virtualized SMRP routing algorithm dealing with the routing tasks.

The rest of the paper is organized as follows. Section 2 presents the related work on convergence of cloud computing and networking. Section 3 discusses the proposed model in detail. Section 4 presents the performance evaluation and Section 5 concludes the paper.

2 Related Work

2.1 Convergence of Networking and Cloud Computing

Networking is a key element for providing data communication in cloud and distributed data centers. A promising approach is the virtualization of networking resources termed as “network virtualization”, the key attribute of future networking paradigm. It enables Network as a Service (NaaS) that allows network infrastructure to be exposed and utilized as network services composed with computing services in a cloud environment. Research efforts on NaaS include network service description, discovery and composition conducted on scattered fields across telecommunications, computer networking, web services and distributed computing [7]–[9].

Virtualization allows combined management, control and optimization of networking and computing resources in a cloud [10]–[12]. In a convergence framework, both networking and computing resources are virtualized into services using the Service Oriented Architecture (SOA) principle and thus appearing as a single collection of dynamically provisioned resources. NaaS enables matching cloud service requirements with networking capabilities using the appropriate network services. The early efforts with intelligent networks and the API standards had an overlay service architecture defined on top of a physical network infrastructure. It extracts service intelligence into dedicated service control points with a simpler approach. However, it lacks mechanism for realizing the separation of service provisioning and network infrastructure.

Recent research tries to apply semantic web techniques in the network realm and develop ontology specifically for describing network services in a machine-readable format. Resource Description Framework (RDF) [13] describes network elements and topologies with an objective of providing a common semantic to applications, network and service providers for unambiguous communication. However, the current usage focuses on connection-oriented optical networks. Network Resource Description Language (NRDL) [14] is developed in order to facilitate abstraction of networking resources using an interaction among network elements. Virtual eXecution Infrastructure Description Language (VXDL) [15] is developed for network and computing resource description with virtualization support. However, several features for network virtualization is not supported in VXDL schema. The resource description schema proposed in [16] includes entities of substrate and virtual resources and attributes that are necessary for supporting a network virtualization framework for IP infrastructure provisioning.

Service discovery plays a vital role in selecting and discovering the network services that meet the requirements for cloud service provisioning. An overview of existing solutions for service/resource discovery for wide variety of networks has been presented in [17] and [18]. The combination of cloud computing and networking requires a coordinated service management and heterogeneous service discovery making heterogeneity a vital constraint. However, due to the large scale networking for cloud computing, frequent update of network service information will generate a large amount of communication and processing overheads.

The elementary building blocks can be composed into more complex services [19], [20]. Scale [21] is based on the requirements from telecom, making its composition methods significantly different from those of the well established and standardized languages. The convergence between the future internet and cloud computing leads to an ultra large scale integrated networking and computing environment. Hence, scalability is an important requirement for service composition mechanisms designed, due to the potentially large number of services involved in composition.

2.2 Vehicular Cloud Services and Models

Dedicated Short Range Communications (DSRC) enabled cars to have varying levels of resources with some having extra storage and processing capabilities that they may want to rent out to other vehicles. Vehicular cloud makes three types of computing services possible 1) Network as a Service (NaaS) where smart vehicles owning internet connections through the cellular network offer their extra bandwidth for a certain fee; 2) Storage as a Service (STaaS) where smart vehicles with high onboard storage capacity offer additional storage in situations where several users are sharing vehicle hardware at the same time or the users want to have a backup copy of their data on the external repository; 3) Data as a Service (DaaS) where smart vehicles use a part of its storage as a data cache for storing data for consumers and charge it on the data size.

V-Torrent [22] and Code-Torrent [23] allow nodes to exchange messages using User Datagram Protocol (UDP) within the direct communication range of one another. CarTorrent [24] uses UDP as the transport protocol and plain Ad Hoc On-Demand Distance Vector (AODV) protocol for routing. VehiCloud [25] works by vehicles communicating their predicted future locations to a central server on the internet where the server determines optimal routes by applying linear problem solving techniques.

VNLayer [26] applies a state machine for the leader election procedure for the virtualization of resources. However, the model enforces a layout of equally-shaped and equally-sized regions, neglecting the presence of obstacles and adverse propagation conditions. The state machine applied for the leader election procedure may react slowly for leader withdrawals and loss of control messages. Also, the selection of one leader in each region leads to single point failure and limits the amount of data traffic that can be handled.

In [27], a cloud was proposed by aggregating vehicular computing resources. The clouds were considered as a group of largely autonomous vehicles and computing, sensing, communication and physical resources of the cloud were assumed to be coordinated and dynamically allocated to end uses. However, it did not take into advantage the conventional cloud but only focused on vehicular resources. Also, the resources require the authorization of the vehicle owner which may be not available when the vehicle is in steady state. CROWN [28] enables vehicles to discover their required services from nearby moving mobile clouds. Here, road-side units (RSUs) act as cloud directories and interfaces, which make recorded data available to enable vehicles to discover the required cloud services within the communication ranges of a RSU. However, except for RSUs, the onboard computers were not taken into consideration and were not made available to end users.

The work in [29] made use of the cloud computing resources through the RSUs for the vehicles to get benefitted from private and public vehicular cloud services and [30] proposed a pure vehicular cloud called Sensor as a Service (SenaaS) for vehicle communication platforms that makes their components including sensors and devices to third party vehicle monitoring applications. However, it lacks the use of the traditional cloud to improve the computing capacity usually requested by vehicles. The architecture proposed in [31] used three cloud types: vehicular clouds (VCs), vehicles using clouds (VuCs) and hybrid clouds (HCs). With the VC, vehicles can interact with the traditional cloud through RSUs that act as gateways.

Authors in [32] dealt with the cloud security issue for vehicular networks by proposing a new secure provisioning model called Vehicle-to-Cloud (V2C). It is composed of an infrastructure that links the automobile user and the infrastructure provider. Three modules were integrated to enhance security. They are the authentication module, the authorization and access control policies module and the assurance module. They manage, identify and authenticate entities in V2C. However, the approach did not use the computing resources of vehicles to reinforce the functionalities of the vehicular cloud infrastructure.

Carcel [33] looks into a cloud assisted system to avoid the issue of obstacles and collision. The system enables the cloud to collect information from autonomous vehicle sensors and RSUs. The request module issues requests for information to the vehicle and the planner module aggregates sensor information to detect obstacles. The system is a kind of Infrastructure as a Service (IaaS) used only to solve an instance of vehicle obstacles. The work proposed in [34] used the cloud-based VANETs to address the issue of seamless access to the internet using Gateway as a Service (GaaS), in order to provide efficient gateway connectivity and enhanced use of internet. However, the primary focus is the internet and does not look into the digital resources of the vehicles that can contribute to the expansion of the traditional cloud computing environment. The authors in [35] presented a detailed study about the importance of vehicular cloud computing (VCC), the applications and services that run on these clouds and the seriousness of the security and privacy issues while accessing these clouds. VCCs can lead to a significant enhancement in terms of safety, security and economic viability of our society. Thus, VCs could establish a large ad hoc federation to help mitigate many types of emergencies. In a planned or unplanned evacuation, there is possible damage to the mobile communication infrastructure, and federated VCs could help a decision support system and offer a temporary replacement for the infrastructure. It emphasizes on the architecture, several interesting application scenarios, security and privacy issues, and key management strategies. The formation of VCCs was also identified and discussed.

The above published works have focused on the scenarios that neglect many of the technical challenges derived from the vehicles' mobility. Unfortunately, a general vehicular cloud model is not yet deployed to serve vehicular customers in terms of their computational needs. Also, the models bypassing the traditional cloud and the use of a single leader approach can result in leveraging the cloud access by limiting the use of resources by the network nodes and can also result in a single point failure.

3 Extended SMRP Based Routing Approach Using Cloud Computing

Because application messages can congest the network, the proposed framework for distributed routing in [1]–[4] was aimed to reduce network traffic by forwarding information only to interested nodes to minimize the use of network resources. The framework was evaluated for the efficiency and scalability in terms of the network overhead and delivery ratio by applying the three filtering methods. Clustering was used for group subscriptions with the efficiency of clustering tested with hierarchical and iterative clustering methods. The delivery ratio considerably increased with the use of advertisement based optimization when compared to subscription semantics and least constraint subscriptions.

However, changes in the network topology reflected changes in delivery ratio. The delivery ratio was higher in highway scenarios as the probability of nodes to stay in a cluster was higher when compared to city and rural based scenarios. Also, the network experienced flooding with the least constrained subscription routing when the nodes subscribed to almost all the events in the network. With subscription semantics, larger multicast groups were formed when compared to advertisement semantics. Nevertheless, advertisement based routing showed minimum overhead when compared to the other two methods. However, advertising intervals still had an impact on the network in terms of increased overhead.

Advanced sensing and communication equipment have become commonplace for modern road vehicles. Vendors are even working to integrate smart phones and tablets in the cockpit. This technological scene has propelled research in the area of ITS with plenty of different approaches for the vehicles to exchange data in ad-hoc networks and with servers on the internet through Wi-Fi communications with roadside access points or cellular networks. Far beyond classic safety-related applications, many providers have been looking at opportunities to offer other services, ranging from environmental monitoring to location-specific advertising and mobile entertainment.

Cloud computing is a network access model that shares a large number of computing resources transparently and ubiquitously. It accomplishes remote delivery of resources using the concept of virtualization. The technique uses the concept of virtualization technology in which a physical resource of a cloud can be shaped into a logical or virtual resource as required. It refers to both the applications delivered as services over the internet and the hardware and software that provide these services. The combination of the hardware and software is called the "cloud". When it is available to the public it is called the "public cloud" and the service called the "utility computing". The internal data center is called the "private cloud" which is not made available to general public.

3.1 Proposed Extensions from a Cloud Computing Perspective

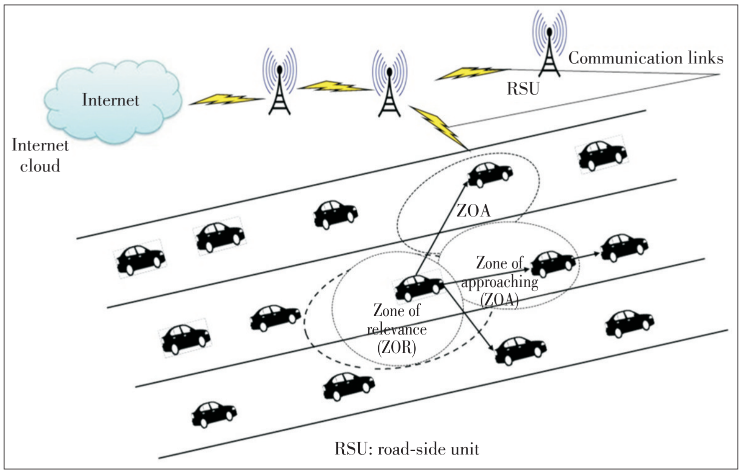
Fig. 1 presents the SMRP based cloud model. In the proposed extension of our framework to the cloud based model, we follow a part of the work in [36] that includes three clouds: vehicle to vehicle (V2V) cloud, vehicle to roadside (V2R) cloud and the internet to enhance the efficiency of our model including the infrastructure based routing. The lower layer of the framework follows the IEEE 802.11p protocol. The model in builds resource virtualization protocols with three different types of clouds. The cloud architecture is divided into different layers to serve different purposes. Middleware systems hide the implementation details of underlying technologies and provide support for the integration of specific applications deployed on vehicular cloud.

The proposed architecture is inbuilt with three cloud models: V2V cloud, roadside cloud, and internet cloud.

1) V2V Cloud

The V2V cloud is formed by a group of cooperative vehicles considered as mobile cloud sites. The group of vehicles shares their computation, storage and spectrum resources. Each node in the cloud can access the cloud and utilize services for its own purpose. Through cooperation, the physical resources of nodes are dynamically allocated on demand. The overall utilization of resources is considerably enhanced as the availability of resources is much more when compared to the resources inbuilt in a single vehicle.

In order to keep track of the formation of the cloud and the service access and to maintain a fair implementation of the cloud, this framework adopts controller nodes (CN) as a partially centralized entity to control the regular updates of the cloud and the service access. The CN is responsible for creation, maintenance and deletion of the V2V clouds. All the clouds register their resources with the CN and the resources are further scheduled to the nodes that place the request for resourc-



▲**Figure 1. A cloud based model based on SMRP routing.**

es. The cloud model guarantees the maximum utilization of resources however at the cost of additional computation overhead at the CNs. In order to overcome the single point of failure, the model uses more than one CN in a geographic zone depending on the communication range. A CN is selected based on the request and response messages exchanged between nodes during the formation of cloud in a geographic zone. Once the geographic zone has been defined the nodes are nominated as CNs with respect to the earliest responses exchanged to be selected as a CN.

The formation of the geographic zone is initiated by broadcasting hello packets. It contains the payload about the group formation in the geographic zone. The hello packet contains the node IDs the preference request to be elected as a CN, and the necessary control information. The packet is transmitted with time-out information. Once the time expires, no nodes can join the geographic zone as the zone is defined group of nodes. The nodes having preference to be elected as the CN will be checked after the group formation. The node that has forwarded a preference request will be elected as the CNs for that particular geographic zone. Since the model includes the assumption of more than one CN to overcome the single point of failure, more than one node are selected as CNs.

2) Roadside Cloud

The roadside cloud is a collection of RSUs and implements the communication between the nodes and RSUs. The vehicles can access the RSUs using the SMRP routing. A vehicle can select a nearby roadside cloud and customize a transient cloudlet for use. The cloudlets accessed via the RSU clouds are transient as they serve the vehicle only for a while. When the vehicle moves out of the communication range of the RSU cloud, the vehicle has to customize a new cloud from the RSU cloudlets.

3) Internet Clouds

The internet cloud acts as the central cloud. The internet cloud is a big pool of resources when compared to the V2V and the roadside cloud. The resources are mainly used for complicated computation, massive data storage and global decisions. The deployment is conducted by using commercial software platforms. The access of information from this cloud is made possible through cellular communications. The internet cloud is accessed by the RSU in situations with the necessity of larger chunks of data which is later made available to the vehicle nodes through the V2R cloud.

3.2 Information Routing Between the Clouds Using SMRP

Vehicles can discover a RSU by V2R communication directly (when the vehicles are in the range of RSU) or V2R communication through V2V communication (if the vehicles are not in the range of RSU). The information accessed by a node is transmitted through the network using the working principles of SMRP [1]. However, the group membership and links in the network have to be updated every regular refreshing intervals. The connection establishment using SMRP follows the following guidelines.

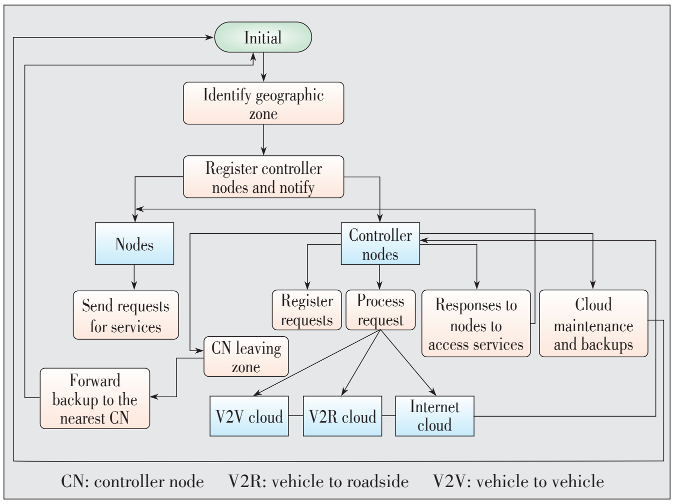
1) Zone of Relevance (ZOR) Creation Phase: Each node identifies the geographic zone ZOR based on the velocity and direction from GPS to share the resources or services. The connection among the nodes in the geographic zone is obtained by broadcasting a hello packet over the network. A receiver then builds or revises the entry in its routing table.

2) Message Dissemination Phase: After the geographic zone has been identified, the CNs are nominated in the defined geographic zone followed by placing requests. Once the CNs are identified, the clouds are established with the number of nodes in the specific geographic zone. The details of the cloud which includes the node ID and information regarding the cloud services are stored at the CNs database for maintenance.

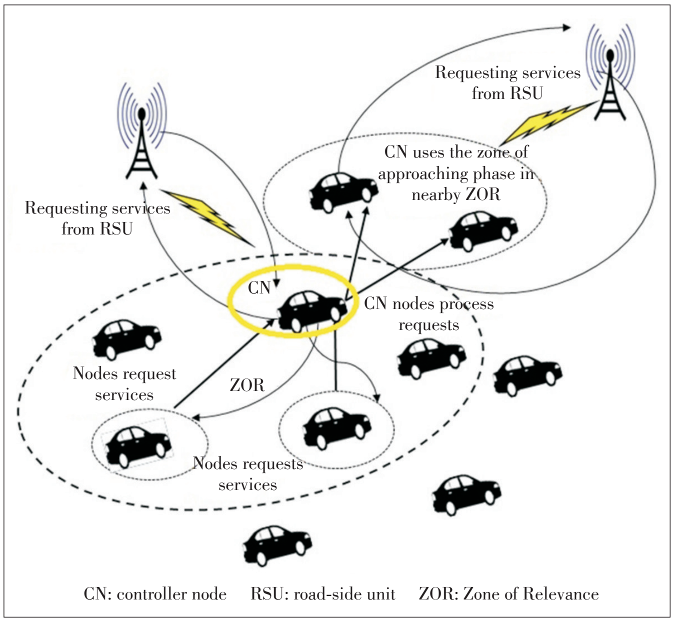
3) Zone of Arrival (ZOA) Growing Phase: If a node cannot find a neighbor close to the apex in the ZOR, the node must perform the ZOA growing phase to solve the fragmentation problem. A series of ZOA is created in order to forward the packet to the next neighboring node if a node is able to find one in the forwarding zone.

4) Maintaining Route and Subscription Updates: A node leaves the group without any prior information. The protocol requires fixed interval flooding of help message to refresh routes and group membership. Packet flooding mostly causes the broadcasting storm problem. Hence, the best choice of refresh intervals is critical for the reliability and performance of the protocol. In this case, the refresh interval can be applied based on the location and mobility information obtained from the GPS. The subscription updates are also performed based on the choice of the refresh interval or update interval.

Fig. 2 shows the flow of the information routing and access in the network, which explains the setup of the network and the routing of information and cloud access. **Fig. 3** presents



▲**Figure 2. Flow diagram of information routing in the network.**



▲**Figure 3. Request process by the controller nodes in the geographic zone.**

the accessing of services and communication among the network nodes and CNs for resource and service access. Once the connection is established using the "hello" packet, the nodes can access and share the required resources and services from the cloud. This access can be extended depending upon the services and resources required whether from the V2V cloud, V2R cloud or the internet. When a node needs to connect to the internet, it requires additional resources (data or resource); it can exploit them through the nearby vehicular clouds by formulating a request packet to the nearest RSU. The request packet contains the geographic coordinates of the user's vehicle.

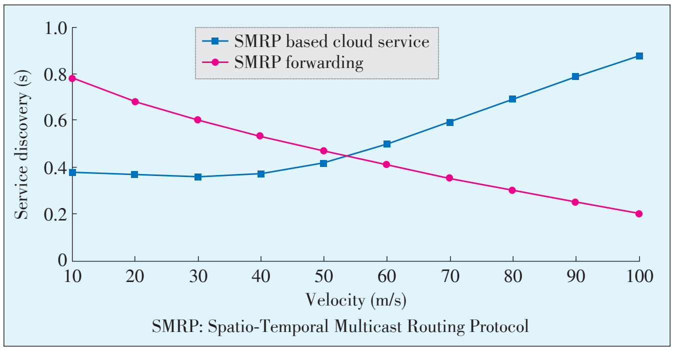
The backups are necessary only in the V2V cloud where the cooperative nodes access resources from the neighboring nodes depending on the availability. As the CN is in charge of the creation, maintenance and deletion of an established cloud, we assume that the CN maintain backup copies of the cloud. The backup mechanism is helpful as when a node leaves a zone, the CN can use the backups to assist in forwarding the data on behalf of the node. The CN will maintain the backup until the cloud is deleted. The backups of any accessible clouds will be stored by CNs of that particular geographic zone in order to keep track of the resource access.

4 Results and Discussion

In order to assess the performance of the framework, we applied the IEEE 802.11p at the PHY and MAC layer levels. The simulation environment comprises both V2R and V2V communications with the nodes trying to download contents from the RSUs and share contents in a peer-to-peer fashion. We assume a simulation area of 2000 m × 2000 m with nodes ranging between [50, 300]. The scenario considers a communication range of 300 m between vehicles and that of 500 m between RSUs and vehicles. We assume that 20% to 50% of the nodes can download and share contents simultaneously from the RSUs and the neighboring nodes considering the availability of the virtual resources. We evaluate the network in terms of the performance of the cloud model with that of the SMRP routing. We also compare the performance of network routing with SMRP and that of the SMRP based cloud model. The network is evaluated in terms of the following metrics:

- Service discovery rate: The time between sending a request and receiving a service
- Average download time: The time between sending the request and exchanging the first data packet
- Queuing delay: The average time the users' request stays in the queue of the CN

Fig. 4 presents the results of the service discovery ratio with respect to the velocity with a network density of 300 nodes. The graph shows that with the standard SMRP routing, the service discovery rate reduces as the velocity increases. The reason is the difficulty in forming the geographic zone and the zone of approaching phase as the nodes move out of the communication range faster. With the use of the SMRP based cloud model, the service discovery increases even with an increase in velocity. The reason is that the cloud model is implemented with the CNs that take care of the cloud registration and maintenance processes. In these scenarios, even when the private cloud nodes leave the communication range, the CNs use the backups to forward the resources and services on behalf of the cloud thereby increasing the discovery ratio. However, at the minimum velocities the network experiences congestions due to the higher number of requests placed for accessing the resources and services and also the time required in the computation at the CNs for the registration and maintenance of clouds. Besides, if the same sets of results are presented by changing the number, the service discovery may show changes. The increase in the number of nodes will increase the delivery ratio while a decrease in the number of nodes will proportionally decrease the service discovery. The reason is that the higher the number of nodes, the higher the probabilities of forming a



▲**Figure 4. Service discovery with respect to SMRP based routing and SMRP cloud based in terms of node velocity.**

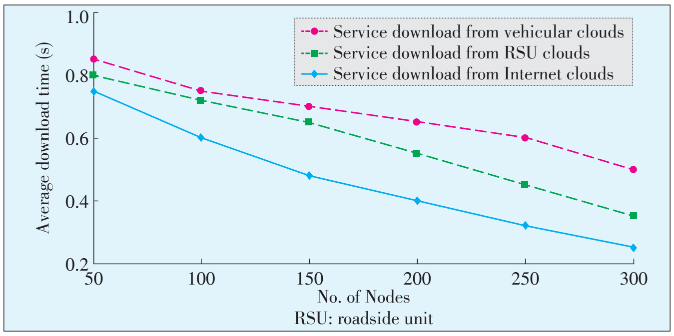
geographic zone with more nodes and hence the higher probabilities of accessing the cloud nodes for the services.

Fig. 5 presents the relative average download times with respect to the service accesses from the clouds. Up to 30% of the vehicles could request contents with the download size of 3 MB. Considering the fact that the vehicle cloud place requests and download the services with the standard SMRP routing, the average download time taken depends on the computation of the geographic zone and the forwarding zones. With the increase in the network density, this computation becomes easier as there are more nods in the communication range and thereby the download time is reduced. The service downloads from the RSUs and the internet clouds include the efficiency of the infrastructure and the availability of the connection. However, the scalability reduces as the vehicles move out of the communication range of the RSU, hence reducing the availability of connection to the RSU and in turn getting access from the internet clouds. The RSU and the internet clouds provide a higher level of service discovery with the minimum download time.

Fig. 6 presents discovery rates with respect to the node density and the change in the number of CNs. The results show that with an increase in the number of CNs, the service discovery rate increases. The reason is that, as a part of the cloud maintenance, the CN stores the backups of data and services when a private cloud leaves the group. The CN then uses the backup to perform the forwarding in a particular geographic zone. In the case that the network partitions lead to network fragmentation problems, the backup may be forwarded to another CN depending on the geographic zones in the partitions. In this way, the forwarding process is carried out until the destination receives the necessary resources and services it has opted for even in the scenarios of node churns and network partitions. Based on the results, the increase in the number of CNs increases the probabilities of nodes receiving the required resources and services. Besides, the increase in the number of CNs is highly desirable as the network is able to achieve a 50% of service discovery with an increase of the CNs in the network.

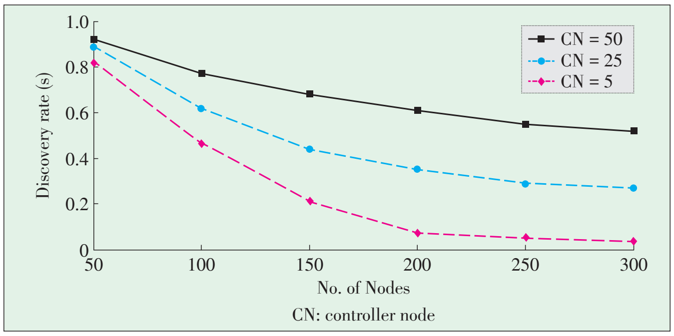
Fig. 7 presents the time for the requests being placed in the queue of the CNs relative to the node density in terms of the number of CNs. The results show that with an increase in the CNs, the queuing delay is not considerably higher even with an increase in the network density. The reason is that with higher number of CNs, the minimum time is required for the computation and processing at the CNs. Nevertheless, with an increase in the CNs around the network area, the workload is shifted among the CNs of the nearest geographic zones in the communication range, which reduces the computation overhead at the controller nodes.

Fig. 8 presents the time delay in the service exchanges. The delay with the standard SMRP is compared with the SMRP cloud model with and without CNs. The results show that without the CNs in the SMRP cloud model, the service exchange



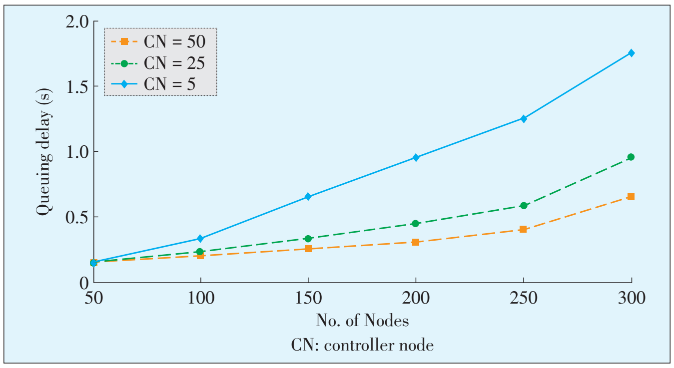
RSU: roadside unit

▲**Figure 5. Average download time from three different clouds with respect to the number of nodes.**



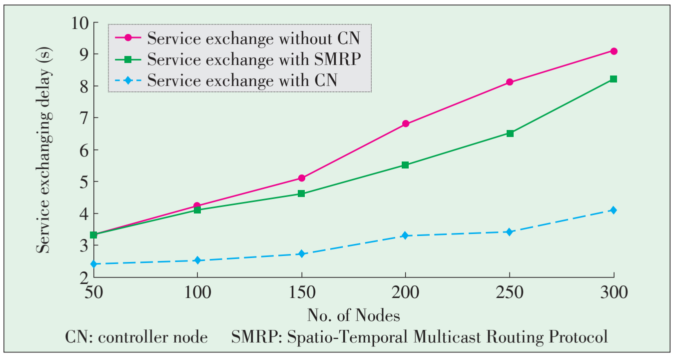
CN: controller node

▲**Figure 6. Discovery rates in the network with respect to the number of nodes with conditions at CN = 5, CN = 25 and CN = 50.**



CN: controller node

▲**Figure 7. Queuing delay with respect to number of nodes with conditions at CN = 5, CN = 25 and CN = 50.**



CN: controller node SMRP: Spatio-Temporal Multicast Routing Protocol

▲**Figure 8. Comparison of delays in exchanging services with standard SMRP, the SMRP cloud model with and without CN.**

delay is significantly higher. The reason is that with an increase in the network density, it becomes hard for the network to handle the increasing number of service requests as there are no centralized in-charge for the computation of the cloud formation and maintenance. However, with the presence of the CNs in the network, the network experiences the minimum delay. The performance of the standard SMRP lies between the two variations as the nodes are only involved in the forwarding of the data packets once the geographic zone has been identified. Hence, there is much less computation required in terms of the service processing.

5 Conclusions

This paper presents a SMRP based cloud computing model for application services in vehicular networks. The simulation results are compared with the standard SMRP protocol for service discovery and exchange. The results show that the cloud model has a higher discovery rate when compared to the standard SMRP routing. Also, the resource and service discovery download time with RSU and internet is comparatively less when compared to the vehicular clouds obtained directly through the SMRP based routing. Our future work will use the game-theoretic methods to study the cooperation among the clouds nodes with respect to the requisition and use of services assuming that any request for a resource, content or a service applies a cost.

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Roundup

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