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A RSU-Aided Resource Search and Cloud Construction Mechanism in VANETs

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ABSTRACT

With the fast development in wireless communications and vehicular technologies, vehicular ad hoc networks (VANETs) have enabled to deliver data between vehicles. Recently, VANETs introduce a Vehicular Cloud (VC) model for collaborating to share and use resources of vehicles to create value-added services. To construct a VC, a vehicle should search vehicles that intend to provide their own resource. The single-hop search cannot search enough provider vehicles due to a small coverage and non-line-of-sights of communications. On the other hand, the multi-hop search causes very high traffics for large coverage searching and frequent connection breakages. Recently, many Roadside Units (RSUs) have been deployed on roads to collect the information of vehicles in their own coverages and to connect them to Internet. Thus, we propose a RSU-aided vehicular resource search and cloud construction mechanism in VANETS. In the proposed mechanism, a RSU collects the information of location and mobility of vehicles and selects provider vehicles enabled to provide resources needed for constructing a VC of a requester vehicle based on the collected information. In the proposed mechanism, the criteria for determining provider vehicles to provide resources are the connection duration between each candidate vehicle and the requester vehicle, the resource size of each candidate vehicle, and its connection starting time to the requester vehicle. Simulation results verify that the proposed mechanism achieves better performance than the existing mechanism.

Keywords : VANETs, Vehicular Cloud, RSU, Cloud Construction, Resource Search

차량 네트워크에서 RSU를 이용한 리소스 검색 및 클라우드 구축 방안

이 윤 형† · 이 의 신††

요 약

무선 통신 및 차량 기술의 발전으로 차량 간 네트워크(VANETs)는 차량간에 데이터를 전달할 수있게 되었다. 최근 VANETs은 차량의 자원을 공유하고 사용하여 부가가치 서비스를 창출하기 위해 차량 클라우드(VC)모델이 등장했다. VC를 구성하기위해서 차량은 자원을 제공하는 차량을 검색해야한다. 하지만 단일 홉 검색은 범위가 작고 통신 범위 밖에 공급차량을 검색할 수 없다. 반면 멀티 홉 검색은 넓은 통신범위를 검색 하지만 차량의 이동성으로 인해 연결 끊김이 잦고 검색에 사용되는 트래픽이 크다. 최근 많은 도로변 장치(RSU)가 도로에 배치되어 차량 정보를 수집하고 인터넷에 연결하는 역할을 한다. 따라서 VANETs에서 RSU를 이용한 차량 자원 검색 및 클러스터 구성 메커니즘을 제안한다. 본 논문에서 RSU는 차량의 위치 및 이동성 정보를 수집하고 수집된 정보를 통해 요청 차량의 VC를 구성하는데 필요한 자원을 제공 할 수 있는 공급차량을 선정한다. 제안 방안에서, 자원을 공급하는 차량을 결정하기 위한 기준으로 각 후보 차량과 요청 차량 사이의 연결 지속시간, 각 후보 차량의 가용 자원 및 요청 차량에 대한 연결 시작 시간을 고려한다. 시뮬레이션을 통해 기존 방안들과 비교하고 성능의 향상을 확인 하였다.

키워드 : VANETs, 차량 클라우드, RSU, 클라우드 형성, 리소스 검색

1. Introduction

With the fast development in ad-hoc wireless communications and vehicular technologies, vehicular ad hoc networks (VANETs) have enabled to deliver data between vehicles through self-organizing vehicle-to-vehicle communication networks [1]. Many projects (e.g., VIC'S [2], CarTALK 2000 [3], NOW (Network-on-Wheels)) and industry groups (e.g., the Car2Car Communication Consortium [4]) have conducted various researches to provide applications for the intelligent transport system by using VANETs. In the intelligent transport system, VANETs enable to

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provide drivers and passengers with safety and convenience, and furthermore introduce new applications for entertainment and environment monitoring [5]. Many literatures on VANETs have been addressed various applications such as car accident warning for active safety, emergency vehicle access for public service, road congestion notice for improved driving, and commercial advertisement for business [6, 7].

VANETs is recently about to evolve with the following emerging paradigms [8]. Frist, vehicles produce and consume a great amount of contents having the property of local relevance. Next, vehicles collaborate by sharing and using their resources to create value-added services. These paradigms enable VANETs to support next-generation vehicular applications such as traffic signal optimization, traffic flow control, and autonomous driving. To enable these paradigms, the technique of cloud computing is necessary to VANETs [9]. To do this, a Vehicular Cloud (VC) model is defined as a set of vehicles that enable to share their own resources [10]. In VANETs, a vehicle is able to construct a VC by using the collection of vehicles' resources. The VC leverages the increasing processing and storage capacity of vehicles. Thus, to construct a VC, a vehicle should search vehicles that intend to provide their own resource.

Many mechanisms have been proposed for searching resource provider vehicles to construct a VC on vehicular environments in the literature [11-15]. They can be categorized two approaches: single-hop search and multi-hop search. In the single-hop search approach, the range of resource searching is limited within only the communication range of requester vehicles [11, 12]. If a requester vehicle does not have many neighbor vehicles in its communication range, it cannot search enough resource provider vehicles to construct a VC due to the small coverage of single-hop communications, and thus causes to high resource search failures. Furthermore, since a requester vehicle might have much less neighbor vehicles due to the problem of non-line-of-sight in urban environments, the problem of resource search failures is even worse. On the other hand, the multi-hop search approach performs multi-hop communications search to find more vehicles by extending the resource searching range [13-15]. However, it generates very high traffics in the network for multi-hop searching. Moreover, since multi-hop communications incurs frequent connection breakages between the resource requester and provider vehicles, it causes more traffics to reconstruct multi-hop communication connections.

To connect vehicles to Internet recently, many Roadside Units (RSUs) have been deployed along roads in vehicular environments [16, 17]. RSUs cover relatively wide areas in communications, collect the information such as locations of vehicles in their own coverages, and maintain connections with the vehicles. Thus, we propose a RSU-aided vehicular resource search and cloud construction mechanism in VANETs. In the proposed mechanism, RSUs collect the information of mobility and resource in addition to the location information of every vehicle within their own coverage. On the collected information, RSUs select provider vehicles enabled to provide resources needed for constructing a VC of a request vehicle. In the proposed mechanism, the criteria for determining provider vehicles to provide resources are the connection duration between each candidate vehicle and the request vehicle, the resource size of each candidate vehicle, and its connection starting time to the request vehicle. Simulation results verify that the proposed mechanism achieves better performance than the single-hop search, the multi-hop search, and the simple RSU search mechanisms in terms of the cloud success ratio and the number of V2V packets.

The remainder of the paper is organized as follows. Section 2 describes the proposed protocol in detail and section 3 evaluates the performance of the proposed protocol through simulation results. Section 4 concludes the paper.

2. Problem Statement and Network model

2.1 Problem Statement

In existing researches, when the requester vehicle requests insufficient resources and service time, it sends a request message to other vehicles within its communication range. However, if required resources and service time is insufficient within single-hop, the cloud cannot be constructed. In this case, to construct cloud, the requester vehicle

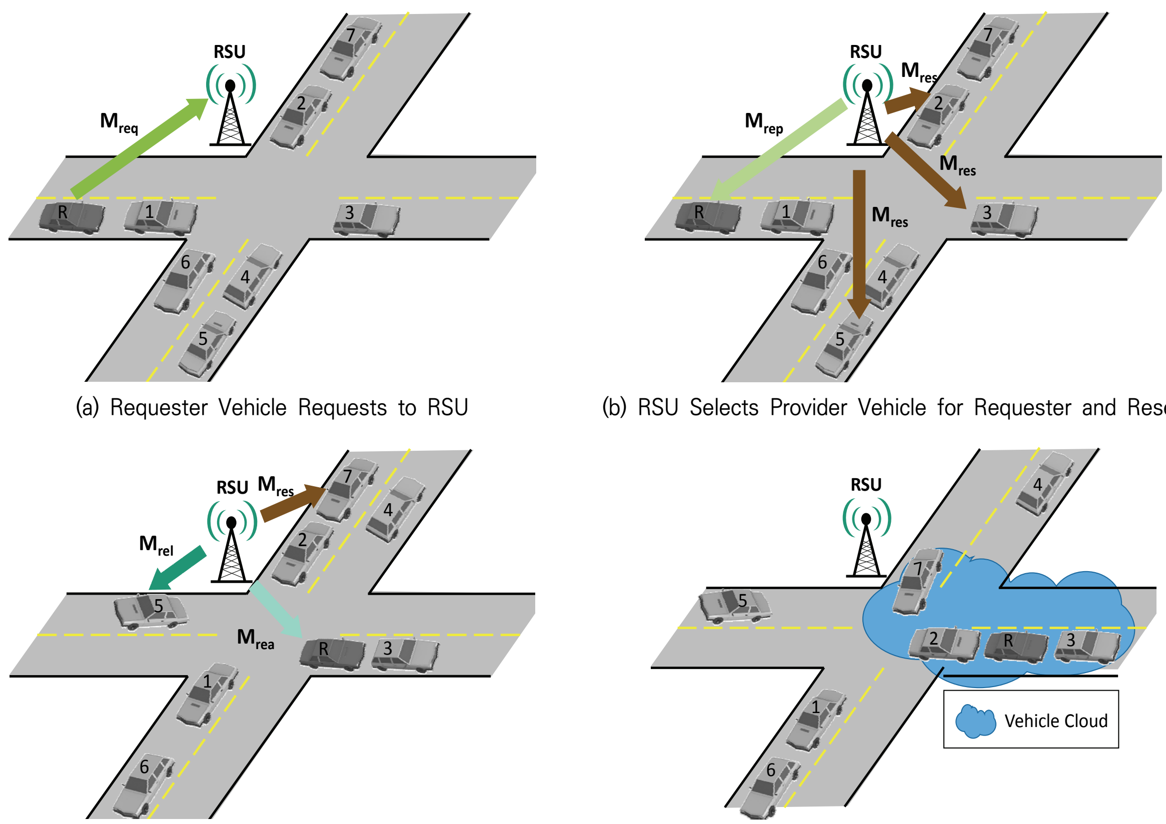
Table 1. Notaion Table

Notation	Description
CST	Connection Start Time
CET	Connection End Time
R_r	Amount of request resource
T_r	Request resource time
R_n	Available resource of provider vehicle n
T_{sn}	CST of provider vehicle n and requester vehicle
T_{en}	CET of provider vehicle n and requester vehicle
T_n	Connection time of provider n and requester
V_{req}	Requester Vehicle
V_{Cn}	Available Candidate Vehicle
V_{Pn}	Provider Vehicle

searches vehicles located in multi-hop communication range to receive insufficient resources and service time. But, the single/multi-hop search for constructing a cloud using only V2V communication increases the delay time until the cloud is constructed and decreases the cloud success ratio due to the mobility problem of the vehicle. As a result, this causes several problems. Although the requester vehicle and other vehicles are located in communication range, the search cannot be performed because of the multi-hop communication characteristics, packet collision or loss. Also, even if the cloud is constructed, as the number of hops increasing, the reliability of service is decreased. There is another problem. In the intersection scenario, the requester vehicle cannot search other vehicles located in the communication range of the requester vehicle because of obstacles such as buildings.

2.2 Network Model of Proposed Mechanism

In this paper, requester vehicle requires resources and service time to construct a VC. The vehicular cloud is constructed by utilizing resources and service time of the requester vehicle and provider vehicles. However, available resources and service time of the requester vehicle are insufficient to construct a VC in single hop. Therefore, the requester vehicle must utilize the resources and service time of vehicles entering the intersection in out-of-sight-zone.



(a) Requester Vehicle Requests to RSU

(b) RSU Selects Provider Vehicle for Requester and Reserve

(c) RSU Reallocates cloud When Sensing cloud is going to Broke

(d) Cloud Construction

Fig. 1. Network Scenario Model Example

There are RSUs in an intersection, and the RSUs can obtain information using V2I communication with all vehicles entering the intersection in four different trajectories. The out-of-sight-zone is to the location of vehicles moving to intersection from other routes that are not visible in the sight of the requester vehicle. For the requester vehicle to obtain information on the vehicles in the out-of-sight-zone, V2I communication via a RSU is utilized. In the intersection, the requester vehicle utilizes V2V communication to construct a VC and calculates reliable connection time using trajectory, location, and velocity information.

In the network model of proposed mechanism, V2I communication and V2V communication adopt different communication method respectively. In general, the communication speed and distance are a trade-off relationship [18]. In the V2V communication providing direct resources, the IEEE802.11g is adopted to provide resources rapidly in an intermittent network and the communication range is 120m for reliable transmission speed for providing VC services. On the other hand, in the V2I communication between the vehicle and the RSU, IEEE 802.11p communication is adopted, which has a reliable communication range (about 1000m) by exchanging information for matching the V2V communication.

3. Proposed mechanism

In this paper, to solve problems mentioned in problem statement, we propose RSU-aided vehicular resource search and cloud construction mechanism. The messages use in the mechanism are summarized in Table 2.

Table 2. Message Table for Proposed Mechanism

Symbol	Definition
M_{req}	A request message from the requester vehicle to the RSU to request scarce resources. (including location, velocity, trajectory, available resource, and service time)
M_{rep}	A reply message from the RSU to the requester vehicle to provide the information of provider vehicles. (including provider vehicle id, available resource, CST)
M_{res}	A reservation message from the RSU to the provider vehicle to reserve resource. (including requester vehicle id, reserve resource, CST, CET)
M_{rea}	A reallocation message from the RSU to the provider vehicle to reallocation vehicles. (including missing vehicle id, new provider vehicle id, provide resource, CST)
M_{rel}	A release message from the RSU to the provider vehicle to reallocation vehicles. (including requester vehicle id)

The requester vehicle V_{req} requires resources and service time to provide insufficient resources for cloud services. Since the resources of V_{req} is insufficient, V_{req} cannot utilize the cloud service. V_{req} must search provider vehicles having the required R_r and Tr in its communication range. The V_{req} sends a request message to the RSU, including its location, velocity and trajectory information.

The RSU receiving the M_{req} from the V_{req} selects V_{Pns} satisfying the requirement of the V_{req} because the RSU maintains information (location, velocity and trajectory) of all vehicles within its communication range using periodical beacon signaling. Also, the RSU can calculates reliable connection time between the V_{req} and all VCns through the spatio-temporal similarity algorithm. The reliable connection time is the time duration between the CST and CET. Finally, the requester vehicle can receive resources and service time from V_{Pns} selected by RSU in the intersection the proposed mechanism is represented sequentially (a) to (d) in Fig. 1.

In the following subsections, we describe the role of the requester vehicle, RSU and provider in details.

3.1 The Role of Requester Vehicle

The role of V_{req} is represented as algorithm 1. For example, let the Vreq requests R_r and Tr in Fig. 1. The V_{req} unicast M_{req} including its location, velocity, trajectory, R_r and Tr to RSU. Upon receiving M_{rep} about the information (resources, CST) of V_{Pns}(Vp2, Vp3, Vp5) from the RSU, V_{req} updates the information in its cloud table as Fig. 2(a). After that, V_{req} requests resources of V_{Pns} based on CST of each vehicle. And V_{req} receives resources from V_{Pns}.

As shown in Fig. 2(a), the V_{req} requests resources on Ts2 to VP2, on Ts3 to VP3 and on Ts5 to VP5. V_{Pns} receiving request provider own resources to the requester vehicle sequentially.

From the RSU, V_{req} receives the M_{rep} including the id of V_{Pns} (V_{P2}, V_{P3}, V_{P5}) and the allocated resource and CST information, respectively. As shown in Fig. 2(a),

ID	CST	Res
2	Ts2	R2
3	Ts3	R3
5	Ts5	Rr-R2-R3

(a)

ID	CST	Res
2	Ts2	R2
3	Ts3	R3
~~5~~	~~Ts5~~	~~Rr-R2-R3~~
7	Ts7	Rr-R2-R3

(b)

Fig. 2. Replace ID 5 to ID 7 on Cloud Table

Algorithm 1: Message Procedure of Requester Vehicle

```
if ( requires to resources ) then
  Vreq sends Mreq to RSU
end if
if (receives Mrep) then
  if(resource is satisfied) then
    Vreq update Cloud Table;
    Vreq requests resource to VPn to VPn at TSn;
  else
    Vreq sends Mreq to RSU;
  end if
end if
if(doesn't receive resource from VPn at TSn)
  delete VPn on Cloud Table;
  send Mreq to RSU about miss resource;
end if
if(receive Mrea from RSU)
  Vreq update Cloud Table;
end if
```

V_{req} updates the information of V_{P2}, V_{P3}, and V_{P5} in its own cloud table. Based on the CST of the provider vehicles through the cloud table, V_{req} requests resources for V_{P2}, V_{P3} and V_{P5}, and provides the resources through V2V communication. V_{req} requests to V_{P2} in T_{s2} time, requests V_{P3} to VP3 in T_{s3} time, and requests resources to V_{P5} in T_{s5} time.

However, due to the characteristic of the vehicular cloud such as mobility and communication delays, the requester vehicle cannot receive the requested resources. If the trajectory of V_{P5} is changed suddenly, V_{req} cannot receive the requested resources. If the requested resource in V_{P5} is not provided, V_{req} requests the RSU again for the missing resource (R_r-R_2-R_3) in the error of V_{P5} and deletes the information of V_{P5} from the cloud table. As shown in Fig. 1 (c), If V_{req} receives information of new provider vehicle such as V_{P7} to replace V_{P5} from the RSU, V_{req} updates the new vehicle in the cloud table. At time T_{s7}, V_{req} requests resources to V_{P7} and receives resources through V2V communication.

In this paper, in general, if a provider vehicle failure occurs before cloud formation, the requester vehicle can receive the M_{rea} to replace V_{P5} with V_{P7} from the RSU that recognized the provider vehicle departure. The V_{req} removes V_{P5} information from the cloud table and adds V_{P7}. At T_{s7}, V_{req} requests a resource to V_{P7} and receives resources. This reduces the costs of cloud reconstruction and enables efficient cloud construction. Finally, V_{req} constructs cloud as shown in Fig. 1 (d).

3.2 The Role of RSU

Algorithm 2: Message Procedure of RSU

```
if(receives Mreq from Vreq)
  calculate each VCns's CST, CET with requester;
  update Information Table;
  select VPn;
  if(resource satisfy)
    send Mrep to Vreq
    send Mres to VPn
  end if
end if
if(detect VPn's issue)
  send Mrel to provider vehicle;
  select new VPn for release_resource;
  send Mrea to Vreq
end if
```

Table 3. Information Table

Id	Res	Next	Position (P_n)	Velocity (V_n)	CST	CET
2	R_2	L	P_{x2}, P_{y2}	V_{x2}, V_{y2}	T_{s2}	T_{e2}
3	R_3	S	P_{x3}, P_{y3}	V_{x3}, V_{y3}	T_{s3}	T_{e3}
…	…	…	…	…	…	…
5	R_5	R	P_{x5}, P_{y5}	V_{x5}, V_{y5}	T_{s5}	T_{e5}
…	…	…	…	…	…	…

This section describes the role of RSU. The RSU operates as in Algorithm 2. The RSU requests location information (P_{xn}, P_{yn}), velocity (V_xn, V_{yn}), and expected trajectory information to V_{Cn} in its coverage periodically and maintains each vehicle information at t0. The RSU can predict the position of the vehicle at t before the next update time through Eq. (1).

The RSU updates the position (P_{xr}, P_{yr}), the velocity (V_{xr}, V_{yr}) and the expected trajectory information of the V_{req} via the M_{req} at t. Using Equation (2), the RSU can determine whether the vehicle is communicating using the vehicle position information. Equation (2) is the Euclidean distance formula and can be expressed as Equation (3). Then, The RSU calculates the CST and the CET between the V_{req} and V_{Cn} using equation (3). This allows the RSU to calculate each Tn of different V_{Cn}. Then, the RSU can update R_n, CST and CET in the information table as shown in Table 3.

$$P_n(t) = (P_{xn}(t) + \int_{t_0}^{t} V_{xn}(t)dt, \quad P_{yn}(t) + \int_{t_0}^{t} V_{yn}(t)dt) \tag{1}$$

$$dis(P_r(t), P_n(t)) < Vehicle\,Coverage \tag{2}$$

$$\sqrt{P_n(t)^2 - P_r(t)^2} = Vehicle\,Coverage \tag{3}$$

Through T_{sn} and T_{en}, the RSU calculates the T_n between V_{req} and V_{Cn}. If CST is less than the current time, the current time is used as CST. Then, based on the resource R_n of the V_{Cs} and the connection time (T_{sn}-T_{en}), The V_{Cn} selected by RSU becomes V_{Pn} to provide resource to the V_{req}. This allows the RSU to immediately calculate and respond to the request message without waiting for all the response messages of the vehicle, thereby reducing the overhead for V_{req} to search for V_{Pn}. After the selection, the RSU transmits the Id, CST, and resources of the selected provider vehicles to the requester vehicle through a M_{rep}. At the same time, the RSU reserves resources of the provider vehicles via a M_{res}.

One of the V_{Cns} satisfying the connection time and having the largest available resources by the RSU. This is because it is the simplest way to construct a cloud of vehicles with a minimum number of vehicles. This minimizes the instability of the vehicular cloud.

Because each VC has a different location, velocity, and trajectory, it has a different CST. Some services may be generous about time and concurrency, but there are other services that are not. Therefore, we prefer to select vehicles with the smallest CST so that all resources can be provided at the same time and the service can be used as soon as possible.

As shown in Fig. 1 (a), VC1 and VC6 are within the communication range of V_{req}. In case of VC1 and VC6, they have fast CST has the past time because it is already in the communication range of the V_{req}. Therefore, when calculating the connection time, the connection time is measured by using the CST as the current time. VC1 has a small CET value because it changes its direction with the requester vehicle at intersection. This leads to a reduction of connection time. So, VC1 that does not satisfy the request time is excluded from the provider vehicle candidates.

The RSU that calculates CST and CET can select a candidate vehicle that satisfies the request time. The RSU maintains a table as shown in Table 3. The RSU selects the candidate vehicle as the provider vehicle in the sequence of resources in Table 3. Assume that the resources of V_{C2}, V_{C3}, and V_{C5} are $R_5 = R_2 < R_3$ and CST is $T_{s5} < T_{s3} < T_{s2}$, respectively. The RSU first selects the V_{C3} having a large resource until satisfying the cloud request resource R_r. Since V_{C2} and V_{C5} have the same resources, RSU first select V_{C2} with a larger CST value, and then select V_{C5}. After the selection, the RSU transmits the Id, CST, and resources of the selected provider vehicles to the V_{req} through M_{rep}. At the same time, the RSU reserves the resources of the provider vehicles via M_{res}.

Vehicular clouds have instability due to vehicle mobility. The proposed mechanism helps to construct a more reliable cloud using trajectory information. However, unexpected errors can cause cloud failures. As mentioned in 3.1, the unexpected situation occurs, the vehicular cloud construction fails. At this time, the RSU can recognize that the V_{C5} is out of the expected trajectory through the periodic signal. As shown in Fig. 1. (c), The RSU recognizing the change of the V_{C5} releases the reserved resource of the V_{C5} through the M_{rel}. Then, the V_{C5} selects the V_{C7} to provide the promised resource (R_r-R_2-R_3) and sends a re-allocation message to the V_{req}. This prevents waste of resources reserved by the V_{C5}. And it minimizes the cost of re-search V_{Pn}.

3.3 The Role of Provider Vehicle

This section describes the role of provider vehicle. The resource provider vehicle operates as in Algorithm 3. Basically, all vehicles periodically report their location information (P_{xn}, P_{yn}), velocity (V_{xn}, V_{yn}), and expected trajectory information when they receive an information request message from the RSU.

When the provider vehicle receives a M_{res} including the CST, CET, Rn and the requester vehicle ID(V_{req}) information from the RSU, provider vehicle reserves the resources Rn to provide for V_{req}. Upon receiving the resource request message from the V_{req}, the provider vehicle provides the resource to the requester vehicle. If the request message from the requester vehicle is not received until CST, the resource allocated for reservation is released.

Algorithm 3: Message Procedure of Provider Vehicle

```
if (receives beacon signal from RSU)
  sends own information to the RSU;
end if
if(receives M_res from RSU)
  hold reserve resource until CST;
end if
if(receives resource request from V_req)
  provide own resource to V_req;
end if
if(receives M_rel from RSU)
  release reserve resource;
end if
```

As shown in Fig 1. (b), When the V_{P2} receives M_{res} including the T_{s2}, T_{e2} information, the resource information (R_2) and the requester vehicle ID information (V_{req}) from the RSU, V_{P2} reserve the resources R_2 to provide for V_{req}. Upon receiving the resource request message from the V_{req}, the provider vehicle V_{P2} provides the resource R_2 to the V_{req}. If the request message from the V_{req} to the CST is not received, the resource allocated for reservation is released.

V_{C5} sends its location (P_{x5}, P_{y5}), velocity (V_{x5}, V_{y5}), R_5, and trajectory information to the RSU periodically. As shown Fig. 1 (b), when the V_{C5} receives the requester vehicle information and the resources (R_r-R_2-R_3), T_{s5}, and T_{e5} information from the RSU via M_{res}, V_{C5} becomes V_{P5}. V_{P5} restricts the use of resources by setting as many reservation resources as the requested resources (R_r-R_2-R_3) among the resources R_5. However, an unexpected mobility may cause an error in connection time. At this time, if communication with the V_{req} fails in CST or a release message is received from the RSU, the V_{P5} releases the resource restriction of the reserved resource (R_r-R_2-R_3) and returns to the original state (V_{C5}).

4. Performance evaluation

4.1 Simulation Environment

This section presents the performance evaluation of the proposed mechanism using NS-3 network simulator that a discrete event simulation models a system [19]. We use the Constant Speed Propagation Delay Model and Range Propagation Loss Model provided by ns3 to consider the communication characteristics such as packet loss and delay. To evaluate the proposed mechanism, we compare it with three existing mechanism only RSU mechanism that has no expected trajectory[13], single-hop V2V, multi-hop V2V[14]. The network topology size is 580x580m^2 with one intersection. The velocity of each vehicle has an arbitrary speed of 40 to 80km/h, and the size of available resources have a random value of 30 to 60Mbytes. Vehicle number, cloud request resource, and request time start with default values, and other parameters are shown in Table 4.

Table 4. Simulation Parameter

Parameter	Values
Simulator	NS-3
Transmission Range(V2V)	120m
Transmission Range(V2I)	1000m
Base Protocol	IEEE 802.11a IEEE 802.11p
Topology Size	580x580(m^2)
Simulation Time	10s
Vehicle Speed	40~80(km/h) [Random]
Provide Vehicle Resource	30~60(Mbytes) [Random]
Vehicle Number(default)	30
Cloud Request Resource (default)	150(Mbyte)
Request Time (default)	2s
Trajectory Error Rate	10(%)

To evaluate the performance of the proposed mechanism, we compare the performance of each mechanism for cloud request time, cloud request resource and the number of vehicles according to the following two performance factors. Cloud request time is the time duration while the requester vehicle requests to the RSU and receives resources to construct the cloud. Cloud request resource is that the amount of resources to construct the vehicular cloud by the requester vehicle. The number of vehicles is the density of vehicles in the network topology. Cloud Success Ratio (CSR) is the rate that the requester vehicle successfully receives and service time from provider vehicles and completes the vehicular cloud construction. The number of

V2V Packet is the amount of vehicle communication control messages that are consumed in the network topology until the vehicular cloud of the requester vehicle is completely constructed.

4.2 Simulation results for Cloud Request Time

Fig. 3 shows the CSR for cloud request time. As the cloud request time increases, the mobility of the vehicle causes change of vehicles located in the communication range of the requester vehicle and decreasing CSR. In single/multi-hop V2V cases, these mechanisms cannot consider vehicles located in the out-of-sight-zone due to the limited communication range of the requester vehicle. Thus, the CSR is decreased. Since only RSU mechanism has no information about the expected trajectory, the CSR is decreased. On the other hand, in the proposed mechanism, the requester vehicle can get the information of vehicles located in the out-of-sight- zone through RSU and construct the vehicular cloud at intersection. As a result, the proposed mechanism improved cloud success ratio by 30-50% over the existing mechanism.

Fig. 4. shows the number of V2V packet for cloud request time. The correlation between the increasing of cloud request time and the number of V2V packet is less in single-hop communication range. However, in multi-hop communication range, the packet exchange of multi-hop V2V occurs frequently because of V2V characteristic such as intermittent connection, frequent cloud destruction. Therefore, multi-hop V2V, the number of V2V packet of multi-hop V2V is highly increased. On the other hand, the number of V2V packet of the proposed mechanism and only RSU mechanism are smaller than single/multi-hop V2V because the RSU periodically updates information of provider vehicles and provides it to requester vehicle. As a result, the proposed mechanism decreased the number of V2V packet by up to 90% over the existing mechanism.

4.3. Simulation Results for Cloud Request Resource

Fig. 5 shows CSR for the cloud request resource. As cloud request resources is increased, the number of provider vehicles is increased. The increasing of the number of provider vehicle causes the probability that some vehicles leaving the cloud is increased. Thus, the probability of cloud destruction is increased. In other words, CSR is decreased. Since single/multi-hop V2V have limited communication range, as cloud requested resource is increased, the number of provider vehicles is increased, and it causes the decreasing of CSR. In Only RSU mechanism, although the RSU has large communication range that can cover the intersection, the expected trajectory is not considered, so CSR is decreased. Unlike only RSU mechanism, the proposed mechanism is more efficient because it considers the expected trajectory. Therefore, the proposed mechanism improved cloud success ratio by up to 60% over the existing mechanism.

Fig. 6 shows the number of V2V packets for cloud request resource. As cloud request resource is increased, the number of provider vehicles is increased, it causes increasing of the number of exchanged packets. Typically, the proposed mechanism and existing mechanisms are similar. But, in multi-hop V2V, as the hop count is increased, the number of V2V packets is highly increased. However, the number of V2V packets of the proposed mechanism is smaller than existing mechanism because the requester vehicle uses information from the RSU. As a result, the proposed mechanism decreased the number of V2V packet by up to 60% over the existing mechanism.

4.4 Simulation Results for Vehicle Number

Fig. 7 shows CSR for the number of vehicles in network. As the number of vehicles is increased in network, CSR is increased. This is because an increase in the number of vehicles means an increase in the number of vehicles that can be considered for cloud construction. Only RSU mechanism shows an increase in the success rate as the number of vehicles increases, but there is a large instability of the cloud success rate because only the current speed information is used instead of the expected trajectory information. In the case of single-hop V2V, as the number of vehicles increases, CSR increases due to the increase of vehicles in single-hop. Multi-hop V2V has better performance than single-hop V2V because its communication range is larger. The proposed mechanism improve cloud success ratio by 10-50% over the existing mechanism because it uses the wide communication range of RSU and the expected trajectory information of provider vehicles.

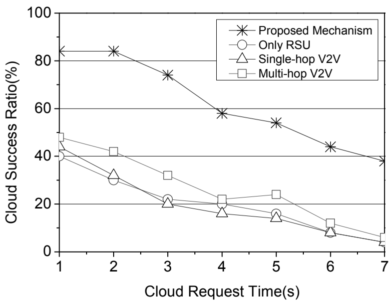


Fig. 3. The Cloud Success Ratio for the Request Time of Requester

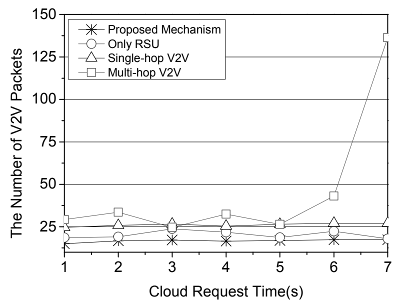


Fig. 4. The V2V Packet Number for the Request Time of Requester

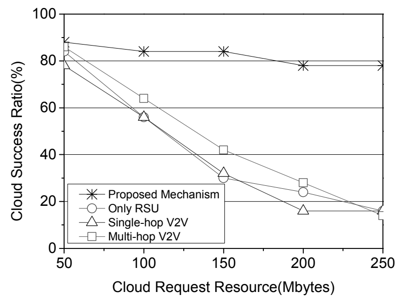


Fig. 5. The Cloud Success Ratio for the Cloud Request Resource of Requester

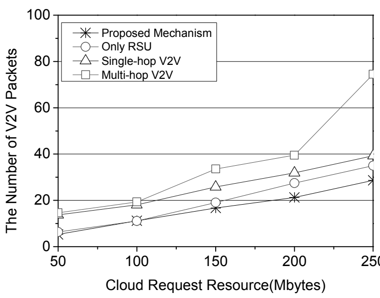


Fig. 6. The V2V Packet Number for the Cloud Request Resource of Requester

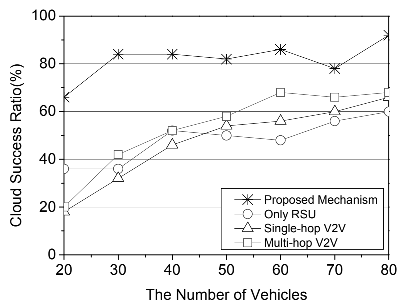


Fig. 7. The Cloud Success Ratio for the Vehicle Number

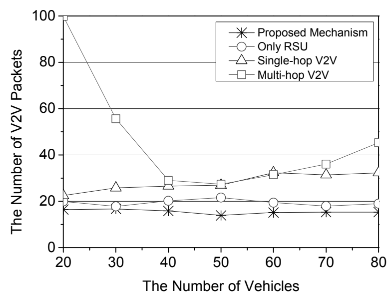


Fig. 8. The V2V Packet Number for the Vehicle Number

Fig. 8 shows the number of V2V packets for the number of vehicles in network. In the case of using RSU, since the information of RSU is utilized, the change of V2V packet due to the increase of the number of vehicles is insignificant. In the case of 1-hop V2V, as the number of vehicles increases, the number of vehicles considered in the search process increases, so the number of V2V packets increases. In case of multi-hop V2V, when the vehicle number is 20, 30, high V2V packet amounts are represented. This is because when a vehicular cloud cannot be constructed within single-hop, many control packets are generated because the communication range needs to be extended to construct the vehicular cloud. As the number of vehicles increases to 40, the construction ratio of single-hop vehicular cloud increases, and a packet amount similar to single-hop V2V. However, as the number of vehicles increases, the number of packets increases at the point of starting the multi-hop procedure. As a result, it has more control packet than single-hop V2V. As a result, the proposed mechanism decreased the number of V2V packet by up to 65% over the existing mechanism.

5. Conclusion

In this paper, we propose RSU-aided vehicular resource search and cloud construction mechanism. Since the RSU has advantages in terms of computing capacity and communication range to construct a vehicular cloud, RSU can selects provider vehicles satisfying the requirements of the requester vehicle based on CST and CET. In the proposed mechanism, the requester vehicle constructs vehicular cloud using RSU more efficient than V2V cloud construction for cloud services. Simulation results show the proposed mechanism is more efficient on cloud success ratio and minimize control packets than existing mechanisms.

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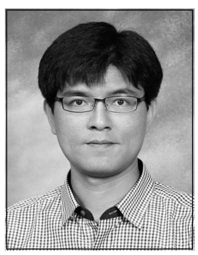

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