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Dynamic Priority-Based Efficient Resource Allocation and Computing Framework for Vehicular Multimedia Cloud Computing

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ABSTRACT In intelligent transportation system, smart vehicles are equipped with a variety of sensing devices those offer various multimedia applications and services related to smart driving assistance, weather forecasting, traffic congestion information, road safety alarms, and many entertainment and comfort-related applications. These smart vehicles produce a massive amount of multimedia related data that required fast and real-time processing which cannot be fully handled by the standalone onboard computing devices due to their limited computational power and storage capacities. Therefore, handling such multimedia applications and services demanded changes in the underlaying networking and computing models. Recently, the integration of vehicles with cloud computing is emerged as a challenging computing paradigm. However, there are certain challenges related to multimedia contents processing, (i.e., resource cost, fast service response time, and quality of experience) that severely affect the performance of vehicular communication. Thus, in this paper, we propose an efficient resource allocation and computation framework for vehicular multimedia cloud computing to overcome the aforementioned challenges. The performance of the proposed scheme is evaluated in terms of quality of experience, service response time, and resource cost by using the Cloudsim simulator.

INDEX TERMS Intelligent transportation system, multimedia cloud computing, vehicular networks, quality of experience, multimedia contents processing, response time, smart vehicle.

I. INTRODUCTION

These days automobile industry in collaboration with the academia is focusing on autonomous or driver-less vehicles all around the globe, in which the fast Internet is a primary need. These smart vehicles can take high resolution images, record videos, and need to process many sensory data for their successful and smooth drive, and to enjoy a range of multimedia applications and services from comfortability to entertainment [3] as shown in Figure 1. Furthermore, such smart vehicles can communicate and share various types of information, such as road map images, road safety, and traffic load information for safe driving with each other via a roadside infrastructure. Furthermore, such vehicles can also exchange many other information (e.g., automatic parking, map location, Internet access, cooperative cruise control and driving, security distance and collision warnings, driver assistance, and dissemination of road information [1], [2]. Thus, overall vehicles are producing a huge amount of critical and delay sensitive data which required on-time processing to ensure on time delivery to maintain the quality of experience. However, due to limited storage and computational capabilities such a huge amount of multimedia-related data cannot be processed on the standalone onboard devices. Furthermore, intermittent connectivity, short radio communication, lack of bandwidth, and high mobility can make the task more challenging.

FIGURE 1. Vehicle equipped with real-time and multimedia applications for efficient and smooth driving [4].

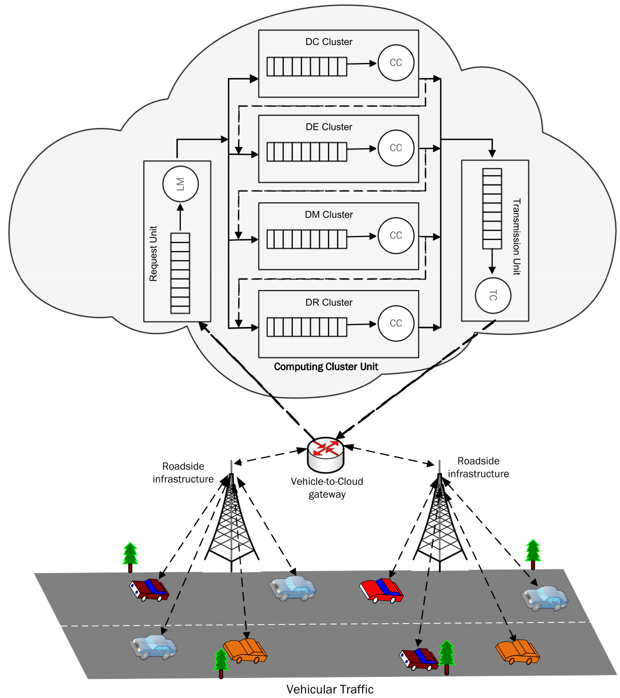


FIGURE 2. Multimedia-oriented cloud computing architecture for vehicular networks.

cloud computing (CC) is an emerging computing paradigm that offers fast and high speed computation facilities as a service to its users without installing any hardware [5]. Thus, CC is an efficient solution for processing of large amount of data at low cost [6]. The integration of CC with smart vehicles is an effective way to enhance the accessibility to multimedia services which also can inspire various potential applications and research topics [9]. The, conventional CC is not suitable for such delay-sensitive and critical multimedia-related applications and services [7]. Thus, to handle such delay-sensitive and critical multimedia applications and services another type of computing paradigm is introduced known as multimedia cloud computing (MCC) [8]. The MCC focuses on how to provide required quality of service (QoS) to multimedia applications. However, multimedia processing of vehicular data is more critical and challenging as it required fast processing, and on-time response at reduced cost. For example the MCC has to process and disseminate the information regarding bad weather conditions (i.e., fog) or some accident happened on the highway and if such information is not process and dissemination to other coming vehicles on-time then there will be more accidents and loss of more lives.

In this paper, we propose a Dynamic Priority-based Efficient Resource Allocation and COMputing (DP-ERACOM) scheme to process the delay-sensitive and multimedia related computation (i.e., video and image data) for vehicular networks at reduced cost based on multimedia tasks priority. In the proposed DP-ERACOM scheme, we divide each multimedia task into four sub-tasks and allocate resources (i.e., MCC resources) dynamically as shown in Figure 2. The proposed scheme has three main computing and processing units: 1) *load manager*, 2) *computing cluster unit*, and 3) *transmission unit*. In DP-ERACOM, vehicular multimedia processing request are received at *request queue* that forward them to *load manager (LM)* for further processing. The *LM* analyzes the nature of incoming requests and assigns them to the particular *computing cluster (CC)*. The CC process the received requests and send them to the next CC or to *transmission unit (TU)* based on the type of requests. Finally, the TU broadcast/unicast the processed request a single or group of vehicles. The proposed scheme handles the priority or urgency of any processing request with the help of *job queues (JQ's)*. In DP-ERACOM, each CC and TU contain single job queue to store all multimedia requests. This concept is demonstrated in Figure 2. However, Table 1 enlists the symbols and acronyms used in our paper. Our main contributions of this paper are listed as below:

- We propose a Dynamic Priority-based Efficient Resource Allocation and COMputing (DP-ERACOM) scheme to process the delay-sensitive and multimedia computations based on multimedia tasks priority for vehicular networks at reduced cost.
- The proposed DP-ERACOM scheme comprises on three main computing and processing units: 1) *load manager*, 2) *computing cluster unit*, and 3) *transmission unit*.
- In the DP-ERACOM scheme, we divide each multimedia task into four sub-tasks and allocate them the cloud resources dynamically.
- The performance of the proposed scheme is compared with the static resource allocation and single datacenter-based resource allocation schemes and evaluated in terms of quality of experience, service response time, and resource cost by using the Cloudsim simulator.

The remaining of our paper is organized as follows: Section II presents the state-of-the-art related to multimedia cloud computing and vehicular networks. Section III deals with proposed DP-ERACOM. Section IV describes our performance and comparative analysis. Finally, Section V, concludes the paper and future work.

TABLE 1. Summary of notations.

Notation	Description
α_t	Time to collect job request from vehicles
N	Number of task received in time α_t
R_Q	Request queue
LM	Load manager
χ_{α_t}	Computing resource at time α_t
CC	Computing cluster
DCC	Data conversion cluster
DEC	Data extraction cluster
DMC	Data matching cluster
DRC	Data reconstruction cluster
TU	Transmission unit
P_Q	Priority queue
λ	Arrival rate
ϵ	Predefined threshold for delay

II. RELATED WORK

This section summarizes the state-of-the-art related to the vehicular data processing and resource allocations methodologies especially for delay-sensitive, critical, and QoS demanding multimedia contents.

In order to minimize the average offloading delay, a learning-based offloading scheme for VCC is proposed in [25]. In the proposed scheme, "an adaptive upper confidence bound algorithm" is developed based on the multi armed bandit theory which makes it adaptive for time varying action and load space. In [26], Ashok *et al.* introduced a heuristic scheme for offloading vehicular tasks and their scheduling over the cloud. The authors compared the proposed scheme with the on-board computation scheme and measures the performance in terms of response time. In [27], Limbasiya *et al.* introduced a scheme to verify the correctness of the received information from the VCC to prevent the security attacks, such as modification, man-in-the-middle, plain text, and impersonation. The correctness of the proposed scheme is verified against various schemes. Similarly, ID-based signature technique for information verification in the VCC is developed in [28]. In the proposed scheme, the signature verification is carried out with the help of the pseudonymous revocation and batch verification techniques. Message passing among the vehicles in the critical and emergency situations is getting more attention under heavy traffic scenarios. Therefore, in such critical scenarios, it is highly important to verify the source of information. Thus, to achieve this goal a framework called SmartVeh is introduced in [29]. In the proposed scheme, an encryption technique based on attributes is developed to securely share the message among the vehicles. Furthermore, in the proposed scheme all heavy computations, such as singing certificate, encryption and decryption are outsourced on the cloud or RSUs.

In order to deal with the problem of spectrum scarcity a cognitive radio relay-based communication scheme is introduced in [12]. In the proposed scheme, an optimization is formulated to increase the network lifetime and save the vehicles power. Primary user (PU) transmissions are protected by using energy-based PU detection scheme, in which PU arrival probability is calculated based on the energy detection technique. In [11], the authors proposed a channel assignment scheme for VANETs, in which vehicles dynamically adopt the contention window (CW) size based on the vehicle's speed. In order to support the VANETs services, such as the speed-based lane changing, time of arrival (TOD), and collision avoidance some new methods are suggested in [16]. The performance of the proposed algorithms is tested in both the network simulator-2 (NS-2) and simulation of urban mobility (SUMO) simulators. Moreover, an on-board mobile-app is designed for efficient, smart, and remote traffic monitoring. In [17], the authors addressed the message on time delivery problem in VANETs. The authors formulated the problem as bi-objective binary linear programming. Moreover, the proposed solution has two main objectives; 1) extending the network lifetime by using the roadside units (RSUs) as relay nodes and also sensing is essential for them, and 2) ensuring the on-time delivery of sensed information to the sink nodes. A distributed resource management scheme for real-time applications in VANETs is introduced in [18]. The proposed scheme allocates the access time window (ATW) to RSU's, traffic flows, and access rates dynamically based on the hard reliability collisions constraints. Moreover, the authors proposed a memoryless scheduler for optimizing the network utility. The same authors extended their work in [19] and proposed an adaptive and distributed resource allocator scheme for cognitive radio-enabled VANETs. The main objective of this scheme is to enable the computing and battery limited vehicles to exploit the vehicular-to-infrastructure wireless fidelity (WiFi) connections for traffic offloading from remote and local cloud by using the cognitive radio-enabled wireless channels. The authors formulated the resource allocation problem as "constrained stochastic network utility optimization problem", in which the serving SRU's dynamically allocated the ATW along with traffic flows, and access rates.

In [20], the authors proposed *a cooperative and adaptive resource scheduling* scheme for VCC known as CARESS, in which requested service is allocated the demanding resource to maintain a certain threshold of quality of service. The proposed scheme also maintains a cache to help the vehicles during searching of required resources. Furthermore, to facilitate the vehicles in searching and managing the required resources, the same authors extended their work in [21] and introduced a more efficient resource allocation and research protocol called SERVitES. In the proposed scheme, vehicles share information by organizing themselves into clusters without the help of the RSU. A three-tier architecture for the VCC is introduced in [22] which comprises on roadside cloudlet, vehicular cloud, and centralized cloud. The authors formulated an *adaptive particle swarm optimization problem* to allocate the demanded resources to the resource hungry applications and services (i.e., multimedia services) to meet their demanded QoS requirements from the any of the three-tier cloud architecture.

Intelligent transportation system faces serious frequency-handoff challenges when the vehicles speed crossing over the 300 km/h speed limit. Therefore, in such high-speed scenarios, vehicles cannot perform exchange of information or data computations among each other. Thus, there is a need of designing an efficient cloud-based solution to handle such critical scenarios. So, in order to tackle such a high-speed handoff issues, a novel framework called SVCC-HSR is introduced in [30]. The proposed scheme is comprising on a three-layer cloud-computing architecture, in which some other techniques are also introduced to tackle the other important challenges, such as fast encryption-decryption, authentication, multi-path transmissions, identifier mapping, and packet compression. Vehicular ad hoc networks can greatly improve their storage, computation and sensing abilities by adopting the cloud computing solutions. Thus, a VCC-based model is suggested in [31] to improve the vehicular computational and communication services. The proposed model also addressed other services issues like resource management, security, privacy, and data aggregation. Vigneri *et al.* proposed that the vehicles could be used as mobile caches to meet the increasing demand of Internet contents and reducing the overload on the cellular infrastructure in [32]. In the proposed scheme, users can connect to the nearby vehicle for the related contents temporarily and then the connection is shifted towards the cellular infrastructure after the expiry of the predefined timeline. In [33], the authors focus the underutilization of onboard computational resources and their efficient allocation as per the nature of the applications. Thus, they proposed a scheme for the VCC to efficiently utilizing the onboard computational resources. In the proposed scheme, the vehicular-tasks are divided mainly into three categories for computational purposes and to reduce the response time for more critical tasks they are being computed via a onboard available resources, the less critical and more computational-heavy tasks are offloaded to the VCC and more heavy and least important tasks are being offloaded on the cloud. In [34], the authors proposed that the offline or parked vehicles can be used as a mean of storage for the moving or active vehicles data. However, to reduce the response time for accessing the relevant data or information an efficient and fast schedular is required. Thus, they proposed a schedular called TSP-HVC for the VCC.

In [35], authors introduced a novel channel clustering scheme called ''NOBEL'' for transmitting real time and multimedia contents in MCRNs. The proposed scheme, quantifies the licensed channels based on their available QoS parameters and make them available for SUs to select the licensed channel as per their desired QoS requirements. In [36], the authors proposed a priority-based channel allocation scheme for IoT-based CRNs for transmitting time-critical applications. In the proposed scheme, more channels are reserved for higher-priority SUs to reduce its call-blocking probability and similarity lower number of channels for the low-priority SUs. An efficient real-time and multimedia transmission scheme using RaptorQ is introduced for underlay cellular CRNs in [37]. In the proposed scheme, the packet losses occurred due to interference with PUs are combat using RaptorQ. Moreover, to assist the successful decode at receiver node different time-sharing ratios are adopted. A soft handoff scheme based on fuzzy logic is introduced to reduce the channel switching rate and for enhanced transmissions for CRN in [38]. In [11], Hussain *et al.* introduced an efficient channel access scheme for VANETs under high mobility and dense traffic conditions. In the proposed scheme, the contention window is adjusted dynamically based on the deadlines measured in terms of time. Conventional path planning based on the shortest path is not recommended for the advanced vehicular systems, such as driverless or autonomous vehicles. Therefore, an efficient path planning is a vital task for the modern systems. The authors in [39], proposed a more efficient and optimal path for the critical and emergency situations based on the road conditions, traffic accidents, and traffic congestions parameters. Many resource models have been investigated previously based on the human interaction and sensors in IoT. In [40], the authors have proposed a new resource model based on information, knowledge, extension of data, and wisdom architecture to construct modeling for both entity and relationship. In order to predict the QoS values in IoT, a neural collaborative filtering-based holistic framework is proposed in [41]. The propose scheme is further based on fuzzy filtering technique to cluster the contextual information.

A vehicular edge computing based collaborative framework called *collaborative vehicular edge computing framework* (CVEC) is introduced in [13]. The proposed framework has flexibility to support various vehicular applications and services both in vertical and horizontal collaborations. In [14], a joint VCC and information-centric-based network architecture is considered for VANETs. In the proposed framework, the information-centric network (ICN) is used to defines the ways for contents dissemination and data routing. Whereas, the VCC helps in defining the ways for network service provisioning by bringing the mobile cloud model to VAVETs. A cloud-architecture for VANETs called *VANETs-Cloud* is introduced in [15]. The proposed architecture is further divided into two sub-models; 1) temporary cloud and permanent cloud. Moreover, the VANETs cloud is based on three layers; 1) client layer, 2) cloud layer, and 3) communication layer. The VANETs cloud provides digital services (i.e., computational infrastructures, software, and platforms) at reduced cost. In our preliminary work [10], we introduced an cloud-architecture for multimedia processing. In this work, each multimedia request is kept in a separate job queue for processing; therefore, the multimedia processing architecture with N different job queues makes system complex and difficult to compute.

III. PROPOSED DP-ERACOM SCHEME

In this section, we discuss the proposed DP-ERACOM scheme for vehicular multimedia cloud computing (VMCC). The DP-ERACOM has three main components: 1) VMCC architecture, 2) resource allocation for VMCC and 3) VMCC queuing model.

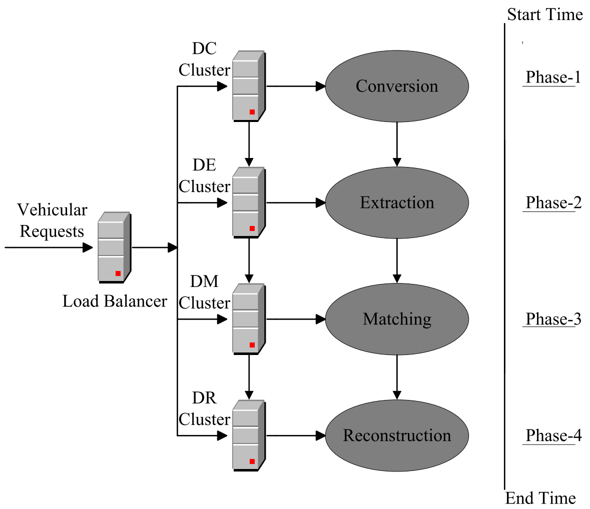


FIGURE 3. **Task level parallel processing procedure.**

Algorithm 1 Priority-Based Task Scheduling and Processing Procedure

input : Global channel set N
output: Sorted Set of available channel K
Initialize request queue with $R_Q \leftarrow$ null
Assign collection time C_t with initial value α_t; $C_t \leftarrow \alpha_t$
Collect requests from vehicles till the expiry of α_t
LM analyzes the R_Q to estimate the total workload N
for $n_i \leftarrow 1$ **to** N **do**
  /* Sort n_i based on priority value */
LM assigns computing resource χ_{α_t} to each computing cluster CC based on the value of total workload N
$DCC \leftarrow \chi_{\alpha_t}$
$DEC \leftarrow \chi_{\alpha_t}$
$DMC \leftarrow \chi_{\alpha_t}$
$DRC \leftarrow \chi_{\alpha_t}$
for $I \leftarrow 1$ **to** N **do**
  /* LM sends multimedia task I into the priority queue P_Q of its appropriate CC */
for $J \leftarrow 1$ **to** N **do**
  /* CC processes the multimedia task J */
  if J *wants further processing step* **then**
    Add J into the P_Q of next CC
  else
    Add J into the P_Q^T of TU
for $K \leftarrow 1$ **to** P_Q^T **do**
  /* TU transmits processed multimedia task K to its intended vehicle(s) */

A. VMCC ARCHITECTURE

In this subsection, we discuss the proposed VMCC architecture for processing vehicular multimedia related tasks, such as image or video analysis. We have divided the whole multimedia processing structure into four phases: 1) conversion, 2) extraction, 3) matching, and 4) reconstruction as shown in Figure 3. This categorization is similar to the presented in [8]. However, in the DP-ERACOM all of these four computation phases are performed separately by four dedicated computing clusters rather than a single computing cluster. Thus, in order to minimize the computing cost, computing resources to each computing cluster are assigned dynamically according to the need or load information. Moreover, in the proposed VMCC architecture each dedicated computing cluster (DCC) contains single priority queue for storing jobs to maintain the priority of the vehicular multimedia tasks. Furthermore, to achieve higher computing performance all of these four DCC's perform execution of vehicular multimedia tasks in cooperative manner as shown in Figure 1.

The VMCC architecture is further divided into four main components: 1) request unit (RU), 2) LM, 3) computing cluster unit (CCU), and 4) TU. Vehicles submit their multimedia computing requests to *RU* via a vehicle-to-cloud gateway by using any wireless interface, such as WiFi, WiMAX or LTE. The *LU* module in VMCC is smart and intelligent module, it not only analyses the nature of the media tasks for task scheduling but also estimates the total aggregated load at any time α_t. This load estimation information will be used further for optimal resources allocation to each DCC. The *CCU* is divided into four sub-computing clusters called: 1) dynamic conversion cluster (DCC), 2) dynamic extraction cluster (DEC), 3) dynamic matching cluster (DMC), and 4) dynamic reconstruction cluster (DRC) as shown in Figure 2 and 3. Each DCC contain a single priority queue, in which *LM* submits vehicular multimedia tasks for computation according to their predefined priority policy/value.

In this paper, we assume that the priority of each vehicular multimedia task is computed and assigned based on the type and nature of the task. For example the least important and critical tasks are assigned the least priority and similarly the most important and critical tasks are assigned the higher priority. Thus, a media task processed by *CCU* is placed in the job queue of *TU*. The *TU* may apply some conversion before forwarding the processed job to vehicle-to-cloud gateway that further forward to the requested vehicle via a roadside infrastructure.

B. MVCC JOB QUEUES MODEL

This subsection present the description of the job queues used in MVCC architecture and their working. Overall, there are three different types of job queues: 1) request's queue, in which all vehicles submit their media tasks that need to be processed by the media cloud, 2) computing or job queues, those store the vehicular media tasks for cloud processing, and 3) transmission queue that store and hold processed tasks before forwarding to the destination(s). This concept illustrated in Figure 2.

C. DYNAMIC RESOURCE ALLOCATION FOR THE VMCC

The main objectives of the proposed dynamic resource allocation scheme are; 1) efficient processing, 2) on-time delivery, and 3) minimizing the computing cost. In the proposed dynamic resource allocation scheme cloud has four dedicated media clusters where virtual machines are installed that are responsible for processing of multimedia vehicular tasks. Computing resources to each DCC is allocated dynamically based on the vehicular multimedia requests load that is estimated by the *LM*. For example if vehicular requests are more than the allocated resources then more computing resources are allocated to DCCs, similarly if the estimated load is less than the already allocated computing resources then computing resources are removed. Thus, based on vehicular load estimation the computing resources are periodically updated to minimize the computing cost and to provide better QoE to moving vehicles.

Algorithm 1 *(Priority-based Task Scheduling and Processing Procedure):* From lines 1–4, the initial assignments and analyses were carried out upon the arrival of real-time and multimedia tasks from various vehicular users in the time span, α_t. From lines 5–7, all received multimedia requests are analyzed and sorted in the form of priority non-preemptive based on their priority values. In this paper, the lower value of priority show the higher priority of task for processing. From lines 8–12, each of the four computing clusters are assigned the resources for job processing. The computing resources to each *CC* is assigned based on the analyses of initial workload received in time α_t. Thus, for next time the amount of computing resources will varies based on the received workload. This is done to utilize the computing resources efficiently and meeting the multimedia tasks delay deadlines. From lines 13–15, the *LM* assigns the each multimedia task to its appropriate *CC* and place to the task into its job queue for further processing. From lines 16–22, the *CC* processes the multimedia tasks and place them into the job queue of further computing unit or transmission unit based on the task processing nature. For example, if the task is fully processed then it will be sent to the job queue of transmission unit for transmission to the intended vehicular user(s) or send it into to the job queue of next *CC* if its processing is not completed yet. Finally, from lines 23–25, the processed multimedia tasks are forwarded towards their intended vehicular user(s) simultaneously to avoid any further queuing delay and to meet the delay deadline of multimedia tasks for achieving better quality of experience (QoE).

IV. PERFORMANCE ANALYSIS

In this section, first we present our experimental settings then, discuss the schemes for performance evaluation and evaluation criteria. Finally, we discuss our simulation results.

A. EXPERIMENTAL SETUP

In this subsection, we provide the detail of our experimental setup. We use the CloudSim [23] simulator for performance analysis of the proposed scheme. Cloudsim is a Java-based library model which is widely used for performing cloud-related simulations [24]. In Cloudsim, the validity of the performed simulations are carried out via a cloud-based content distribution service which sets the corresponding application complexity according to the calculation requests of the service. As discussed previously, we model our scenario into three main components, 1) *LU*, 2) CCU, and 3) TU. We perform simulation on multimedia tasks (i.e., images) and for this purpose, we modified the characteristics of cloudlet class and modeled it as per our requirement. In our proposed scheme, the arrival of vehicular media-tasks follow the Poison distribution with t time interval. We carried simulations under different hardware settings (i.e., MIPS, RAM, and number of CPUs) as given in Table 2.

TABLE 2. Simulation settings.

Sr. no.	RAM	MIPS	CPUs
Setting 1	4096	2100	2
Setting 2	4096	4200	1
Setting 3	4096	2100	1

B. PERFORMANCE EVALUATION SCHEME AND CRITERIA

We evaluate and compare the proposed scheme with the baseline single cluster and static resource allocation schemes. All the four phases related to image processing are being performed by a single cluster in the baseline single cluster scheme. However, in the static resource allocation scheme, resources to each DCC are allocated at startup with no periodic updation of computing resources. We conducted comparisons based on the following parameters:

1) QUALITY OF EXPERIENCE

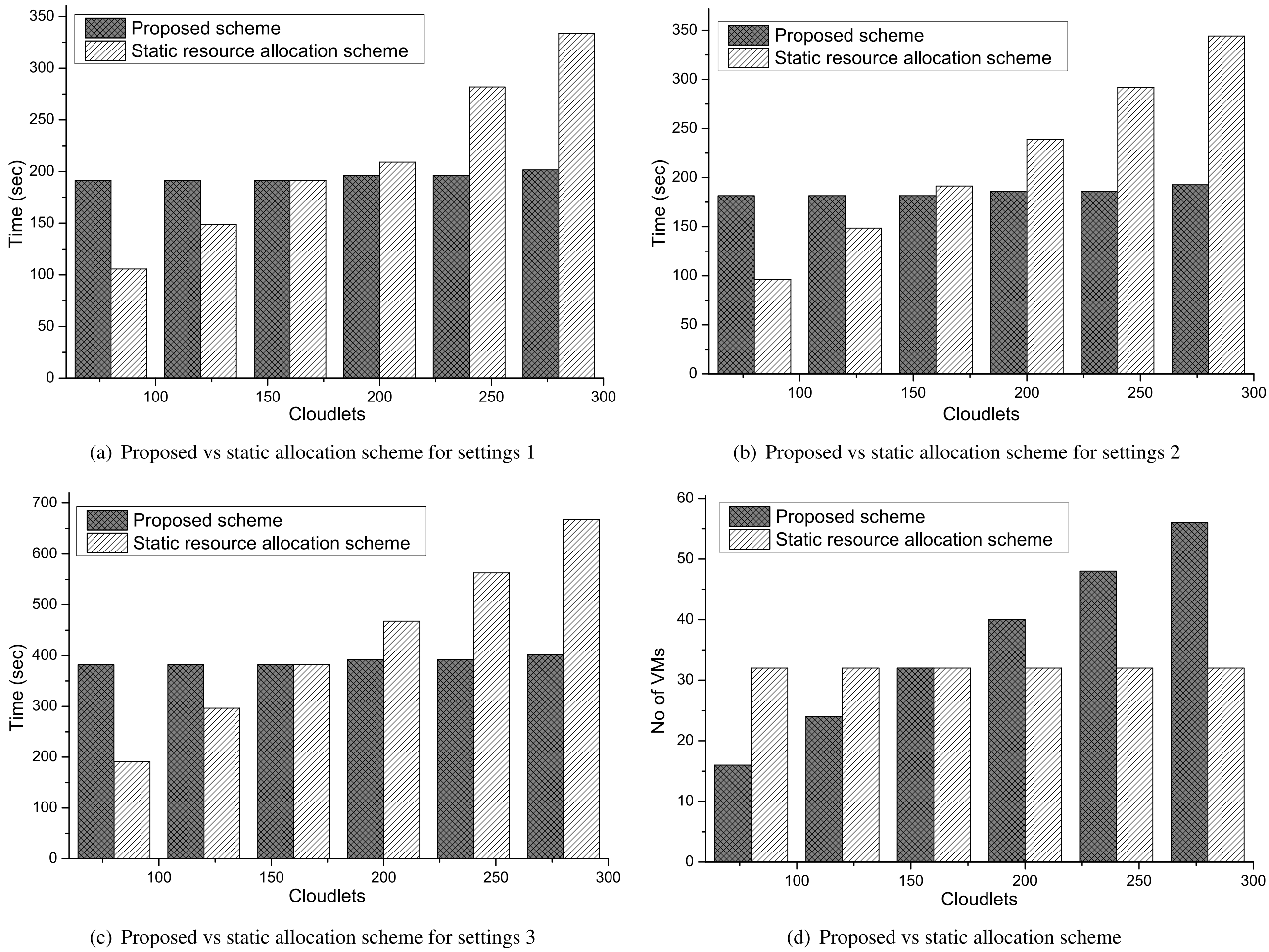
The QoE is measured in terms of end-to-end or SRT time, that is a time measured from vehicle media request initiate phase till vehicle receives its required response. In our paper the QoE is directly proportional to the value of SRT. For example if a particular vehicle receive its required response in-time then it experience better QoE. However, if a particular vehicle do not receive the required response in-time then its experience low QoE. The overall QoE of the proposed system is measured as follows:

$$T^{tot} = T^{sch} + T^{com} + T^{tra} \tag{1}$$

For scheduling all priority-classes, the mean service response time given in [10] as follows:

$$T^{sch} = \frac{\frac{1}{\mu}}{1 - \frac{\lambda}{\mu}}. \tag{2}$$

where the scheduling rate is denoted as μ for processing according to the assigned or allocated priority-classes. Multimedia requests arrival is modeled by using a Poisson distribution with the λ arrival rate. In this paper, we assume high-speed wired communications links among each CC.



(a) Proposed vs static allocation scheme for settings 1

(b) Proposed vs static allocation scheme for settings 2

(c) Proposed vs static allocation scheme for settings 3

(d) Proposed vs static allocation scheme

FIGURE 4. Proposed vs static allocation scheme under different simulation settings.

Therefore, the delay of moving one sub-tasks from one *CC* to another *CC* is negligible. Thus, the mean service time (MST) for multimedia tasks for all four computing sub-phases is given a follows:

$$T^{com} = \sum_{k=1}^{4} T^{com_k} \tag{3}$$

Finally, the MST for computing of all types of priority is given as below:

$$T^{com} = \sum_{j=1}^{N} \frac{\lambda_j T_j^{com}}{\lambda} \tag{4}$$

where N is total multimedia tasks received in time $\aleph_t$ for processing. Finally, the SRT for transmitting all multimedia results towards their intended vehicular user(s) is given in [10] as below:

$$T^{tra} = \sum_{j=1}^{N} \frac{\lambda_j T_j^{tra}}{\lambda} \tag{5}$$

Thus, substituting the values of T^{sch} from Eq. (2), T^{com} from Eq. (4), and T^{tra} from Eq. (5) in Eq. (1), we get

$$T^{tot} = \frac{\frac{1}{\mu}}{1-\frac{\lambda}{\mu}} + \sum_{i=1}^{N} \frac{\lambda_i T_i^{com}}{\lambda} + \sum_{i=1}^{N} \frac{\lambda_i T_i^{tra}}{\lambda} \tag{6}$$

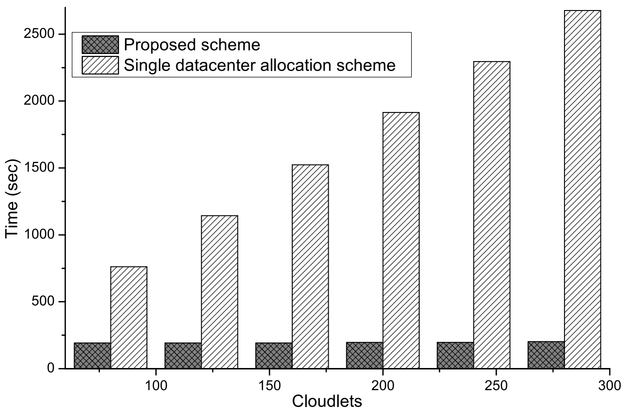
If the end-to-end latency T^{tot} of any multimedia request is below then its given threshold (i.e., the upper bound of service time, ϵ). Then, the end user(s) experience the satisfactory QoE. This QoE constraint is defined as follows:

$$T^{tot} < \epsilon \tag{7}$$

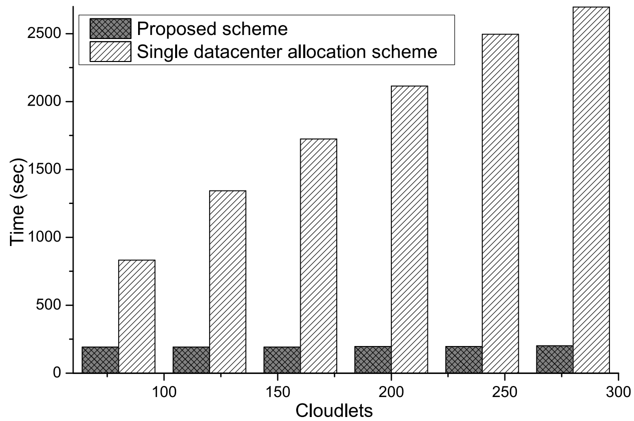
If the above given condition is not met, then more resources are needed to improve the QoE at end user.

2) COMPUTING COST

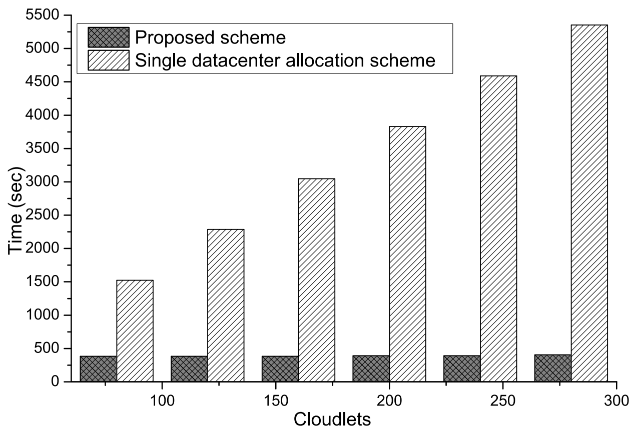
For any cloud service provide, providing the desired QoE at reduced coast is always a challenging task. In this paper, the computing cost is directly proportional to the number of computing resources, such as the no. of virtual machines allocated for computation of any particular media task. Hence, the more no. of idle resources the more will be computing cost.



(a) Proposed vs single datacenter scheme for settings 2



(b) Proposed vs single datacenter scheme for settings 3



(c) Proposed vs single datacenter scheme for settings 4

FIGURE 5. Proposed vs single datacenter allocation scheme under different simulation settings.

C. SIMULATION RESULTS

In this section, we present the simulation results of the proposed scheme compared with the static allocation, and baseline single cluster allocation schemes.

Figure 4(a)-4(d) present the performance evaluation results of the proposed scheme with static resource allocation scheme under various simulation settings (i.e., setting 1 - setting 3) as given in Table 2. Figure 4(a) presents SRT under configurations setting 1 of virtual machines in the media server in which VM has processing speed 2100 MIPS, 2 CPUs, and 4 GBs of RAM. It is clear from the figure that the proposed scheme perform better than the static resource allocation scheme in terms of SRT. In static resource allocation scheme, the resources are assigned once at the beginning of simulation. Under the fewer no. of cloudlets the static scheme performs better. However, as the no. of cloudlets increases the SRT also increase which consequently reduce the QoE at receiver vehicle. As in the proposed scheme the resources are dynamically updated according to the load information. Therefore, the proposed scheme performs better even under more no. of tasks and it provides batter and guaranteed QoE at the receiving vehicle. Similarly, the figures 4(b)- 4(c) show that the proposed scheme perform batter under other simulation settings. Figure 4(d) represents simulation result of the proposed scheme with static resource allocation scheme in terms of number of amount computing resources (i.e., number of Virtual Machines (VMs)) required for computation. Figure shows that with the increase in number of cloudlets the number of VMs also increase. This is because of maintaining a guaranteed QoE to vehicles and providing on-time responses.

Figure 5(a) - 5(c) present the simulation results for the SRT of the proposed scheme with baseline single cluster or data-center based resource allocation scheme under various configuration settings given in Table 2. It is clear from the Figure 5(a) - 5(c) that the proposed scheme outperform the single cluster-based computing scheme. The proposed scheme provides the minimum computation time and consequently, supports the guaranteed QoE for vehicles. However, it can be clearly seen that the SRT increase as the cloudlets increase in single cluster-based computing scheme. This happens as only the single cluster is responsible for performing all four image related tasks. Whereas, in the proposed scheme, a image processing task in divided into four sub-tasks those are further assigned to the four dedicated computing clusters, accordingly. Thus, the proposed scheme performs batter than the baseline single cluster computing scheme in terms of the SRT.

V. CONCLUSION

In intelligent transportation systems, vehicles are equipped with multiple sensors, cameras, and other smart devices that produces a huge amount of multimedia-related contents for processing which cannot be performed by the on-board standalone computing devices due to their limited storage, battery powers, and computation capacities. Therefore, integration of vehicles with multimedia cloud computing (MCC) is highly required as it provide a powerful computing tool that offers the fast and efficient computation of vehicles multimedia applications and services. In this paper, we proposed an dynamic priority-based efficient resource allocation and computing architecture for vehicles to address the challenges of fast response time, guaranteed quality of experience, and minimum computing cost. In our proposed scheme, multimedia tasks are divided into four sub-tasks and assigned to appropriate dedicated computing cluster for processing. Priority non-preemptive queue is used to ensure the on-time response delivery to different vehicular multimedia tasks with different priorities. Moreover, in our proposed scheme, computing resource are dynamically updated based on load information. The performance of the proposed scheme is evaluated using Cloudsim simulator with static resource allocation scheme and baseline single cluster-based computing scheme in terms of the QoE, resource cost, and response time. The simulation results show that the proposed scheme outperforms the baseline single cluster-based computing and static resource allocation scheme.

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