ABSTRACT Despite the surge in a vehicular ad-hoc network (VANET) and volunteer computing research, future high-end vehicles are expected to under-utilize the onboard computation, storage and communication resources. Therefore, this research envisions the next paradigm shift by merging VANET and volunteer computing, which we call VANET based volunteer computing (or VBVC). To date, the potential design system for VBVC has not been characterized. To fill up this gap, we first set forth the scientific classification of VBVC, which uses the automobiles alongside roadside units (RSU) to give computational administrations to different vehicles on the road. We propose a potential framework for different VBVC scenarios. Moreover, we provide an experimental evaluation of VBVC by comparing it with the traditional model in terms of job completion, latency, and throughput. The proposed VBVC performs better when compared with traditional approaches.

INDEX TERMS Ad-hoc networks; Routing; Safety Applications; VANET; Volunteer Computing.

I. INTRODUCTION The need for having more computational resources has always been inspiring human beings to perform various tasks efficiently. Due to the advancements in the ICT and computer networks technologies, various computational paradigms have been proposed to achieve this goal. Due to the surge of mobile technologies, it is very easy for the people to communicate on the go and perform various distributed computing tasks efficiently. The tasks include route finding, accessing various location-based services and emergency response to disaster situations. Similarly, Vehicular Ad-Hoc Network (VANET) has facilitated effective communication among various vehicles, which are connected with roadside equipment [1].

Modern age vehicles are not the same four wheels cart as they were in the past. But are very complex machines that are imagined conveying dependability and security to our driving background [2]. To create strong communication between vehicles on the road and to connect with each other or to transfer the data, was considered as a foreseen dream once which have evolved into the modern VANET [3]. In the past few years, the vehicular VANET concept has evolved from traditional VANET providing safe and reliable services to autonomous vehicles, however, the need for having additional computational resources is always required due to high-level ever increasing requirements. Furthermore, the existing resources must be utilized in an optimal manner and the idle CPU time should be utilized for collective safety and reliability of the passengers. A similar concept also exists in traditional computing which is called VC. This concept uses the extra resources of volunteer devices to provide cheaper services and perform computationally expensive tasks. Innovative techniques that take the fundamental features of volunteer computing (VC) are needed to use these idle resources. This has not been done in the context of VANET. So, there is a need to implement in vehicular networks “VC as a service” (VCaaS), as proposed by Mengistu et al. [6]. Similarly, the cuCloud [7], [8] is a system that can be called a genuine volunteer cloud computing system, which manifests the concept of VCaaS that finds significance in edge computing and related applications. Moreover, for VANETs it must be done in a way, which is autonomous and involves maximum participation of volunteers, thus utilizing resources more efficiently [4].
The authors in [5] have studied the reliability and availability of volatile volunteer cloud computing nodes. The authors have used a multi-state semi-markov process model for prediction. However, this is mainly done in the context of cloud computing. Most of the work in VC is done in wired configurations such as in BIONIC framework [19]. Wireless configurations such as modern vehicular networks where, mobility is a major challenge are still an unexplored domain [2], [9], [10]. Modern vehicles are equipped with processing and storage capacity, which needs to be efficiently utilized. For optimal utilization, the throughput, job completion rate and the latency are considered as important parameters [11]. Novel methods are required for engaging people in volunteer cloud computing. It does not only extend the ability of mobile devices to participate in VC through ad hoc networking, but also provides computing resources for projects for collective benefits [12].

The main contribution of this work is to propose a novel computational paradigm, which efficiently combines VANET and volunteer computing. This is important to use the idle resources of VANETs in an efficient manner and to provide various services to owner of vehicles such as safety and reliability. This new computational paradigm is called Vanet-based volunteer computing (VBVC). A critical part of VBVC is to build an efficient, secure and dependable communication mechanism. We envision that in future there would be a large number of vehicles on the road, which would represent a huge unused computational resource. These huge resources can be utilized in an efficient manner to achieve some useful computational tasks e.g., for road safety, route finding, and emergency management [13].

The main contributions of the paper are:

1) A new computational paradigm called VBVC is proposed which utilizes the idle resources in VANET to promote reliability and safety of on road vehicles.

2) We have performed extensive simulations of the proposed model. Furthermore, we have also provided a comparative analysis with the traditional model. Our experimental evaluation reveals that the VBVC is quite efficient in terms of job completion rate, throughput, latency, and energy when compared with the traditional model.

3) A motivational case study is also provided which provides an example scenario, which can benefit from our proposed VBVC paradigm. Lastly, we have also identified a number of future areas of research, which should be focused by future studies in this domain.

The rest of the paper is structured as follows: Section II describes the background study. Application and challenges are presented in section III. Related studies are presented in section IV. The system model and mathematical formulations along with the proposed methodology are demonstrated in section V. Section VI illustrates the experiment results of our proposed schemes. To finish, the findings of this work along with future directions are presented in section VII.

II. BACKGROUND

This section highlights the basic architecture, requirements, applications, and previous work done in both VANET and VC.

A. VEHICULAR AD HOC NETWORK (VANET)

Firstly, we review VANET, its architecture, applications and challenges. VANET generally consist of vehicles interacting with one another by means of road side unit (RSU). VANET architecture, consist of an on-board unit (OBU), a receiver and a wireless transmitter [9], [14]. It is basically divided into two major domains, i.e., Vehicular Domain and ad-hoc domain. In vehicular domain, OBU is connected to Application Unit (AU). While in ad-hoc, moving vehicles are linked with each other by RSU via a proper gateway (GW) in a multi-hop fashion [11]. The RSU sends a message to the OBU, which is directly connected to the Internet.

Communication in VANET is either V2V, V2I, V2B. The VANET are used for the short-range transmission among the mobile host vehicles and between the vehicles and RSUs see Figure 1. RSU has been considered as one of the significant parts of VANET due to the allocation capacity of distribution centers for combined tasks. Usually, the maintenance and installation cost associated with RSUs are remarkably high. Reis et al., [15], presented standards for choosing a vehicle to assist as an RSU to share the fixed job. A basic VANET model is shown in Figure 2. Likewise, other challenges, such as the random distribution of RSUs and the high-level workload burden, researchers have recommended the utilization of parked vehicles as an extension of RSUs. These vehicles are responsible for allocating jobs to RSUs, and letting vehicles to download updates in a suitable way [16].
B. VOLUNTEER COMPUTING (VC)

VC combines the computational resources of personal devices owned by volunteers [17]. These computing devices are arranged in two patterns; digital and physical. The digital pattern allows volunteers to share their computing devices (software resources) while physical pattern allows volunteers to share their hardware resources for different projects. A VC do not take any monetary incentives for their contributions, but desires to get acknowledgment from the community. Various initiatives have been taken by governments and research organizations in order to develop state-of-the art VC platforms for higher computations at a low cost [18]. For this purpose, it is needed to maximize the number of personal devices for volunteer use in order to fully exploit VC potentials. For instance, the Berkeley Open Infrastructure for Network Computing (BOINC) [19] project has 175,000 volunteers contributing for the handling of 0.85 million active computing devices. The main challenges faced by the VC are: the variable nature of its capabilities and unreliability of computing devices. In order to overcome the issues, there is a need of more volunteers, engagement and a proper mechanism for controlling the unreliability of these computing devices [20]. When compared with cloud computing, a VC does not incur the cost for customers therefore, the use of more computational devices is not limited. A VC involves no financial gains however, it offers points as recognition for volunteer contribution. The VC model overcomes the financial obstacle for accessing computational resources. On the other hand, VC involves less administrative efforts when compared with grid computing [21]. VC systems are based on distributed computing (see Figure 3), which allows large number of users or participants to utilize their idle resources for computationally expensive projects [22]. As VC involves billions of users which specifies more processing and memory therefore, it is important to upgrade existing systems, to fulfil computational need, and to involve more volunteers. Moreover, this has put forth the stress on minimizing manpower by exploiting low cost computational resources [23]. Generally, VC follows a master-worker parallel model. In this model, the master divides large tasks into small chunks and then these tasks are distributed, among the worker nodes.

III. APPLICATIONS AND CHALLENGES

Most state-of-the-art techniques have considered VANETs for various applications such as dynamic road safety applications, effectiveness of VANET to support traffic, and customer privacy etc. Despite many advantages, there are number of challenges in VANET. For instance, high network traffic, provisioning of QoS, transfer speed, security to the vehicle and individual protection etc. [24].

A. APPLICATIONS OF VANETS

VANET applications are divided into three categories [25]. – Safety/Non safety – Intelligent transport – Comfort VANET proved itself to be worthwhile in major applications, but here we are only concerned with safety and non-safety. Table 1 shows the applications of VANET.

| Safety Application | Non Safety Applications |
|--------------------|------------------------|
| Accidental prevention | Traffic Convenience |
| Crash Avoidance | Efficiency Application |
| From various sensors, improve road safety, avoids traffic signal violation, warning for speed, brake lights in emergency, pre-crash sensing, warning for collision, assessment in left turn, warning during lane change, assessment during stop, and forward collision warning | Weather, location of restaurant, media downloading |

B. MOBILITY PREDICTABILITY

Compared with a classical Mobile Ad Hoc Network (MANET), portability designs in VANET are moderately unsurprising because of the known road topology. High vehicle mobility and efficient schedules, it is difficult to predict the portability of hubs. For this reason, there are techniques to predict patterns of changing traffic lights, minimal vehicle speed and street layout format. Irrespective of whether it involves earlier community training, intelligent
forecast estimates, and flawless accessibility, it is important to remember that a VANET creates brand-new applications and policies in VANET with relatively effective standards. It additionally supports location-based services to work with expanded QoS. [26].

C. CHALLENGES
In this section, we discuss the challenges which are common in existing VC and VANET architectures:

1) STORAGE
A number of research challenges need to be addressed until the large scale deployment of VBVC becomes possible. VBVC uses the devices connected to the Internet, and their owner’s volunteered devices as a source of computation and storage for other [27]. The capability of the VBVC include processing power, memory, host-availability, disk-space, network throughput and user-specified bounds on resource usage. VBVC improves applications that are more data-intensive or have larger memory and storage requirements, but storage could be considered as a challenging issue.

2) OPTIMAL TASK DISTRIBUTION
As in VC projects, there is a task-server to carry out work. Volunteers communicate with the server to finish tasks and get new tasks. According to the speed at which the database may execute tasks, the computing power available to the project may be limited. Here, the research question deals with the issue of vehicle communication, the job server and a VC middleware application that is centralized and integrates VANET with VC. In the context of VBVC, VANET based task distribution is equal distribution of a task to nearby available vehicles or voluntarily available to perform certain tasks which will reduce operational cost and by using maximum computational power [28].

3) EFFICIENT BANDWIDTH UTILIZATION
This is a technique that efficiently utilizes communication resources including bandwidth when transmitting delay sensitive messages to a communication system [29]. Its challenging that the message is going efficiently without packet drop or getting lost so its possible that efficient data transmission might get affected in VBVC.

4) ROUTING
Since last few years, routing has been investigated widely. The use of ad hoc protocols requires that each node should be assigned unique address i.e. addressed based topology. This allocation of unique addressed requires a mechanism that can assign an address to specific vehicle. But this does not ensure that there will be no collision [30]. Collisions are still possible moreover, with VBVC it is reduced to some extent. However, it is not possible to completely overcome this issue it is quite challenging.

5) SECURITY AND PRIVACY
Privacy and Security both are challenging in nature. For any type of communication, trust is very important therefore, building a trustworthy relationship between the nodes play a vital role. Moreover, the participant should have access to control what information could be exposed to other service providers and what information must held private [31], [32]. Considering VBVC phenomena, it involves security issue as well as privacy i.e., data loss, personal information exposes etc. As nature of communication is wireless, the data sent via broadcast can be leaked out i.e. anybody can receive. In fact, data contains some private information or sensitive such as the location of a vehicle, internal sensor data, speed, time. Therefore, it should be ensured that this data cannot be shared with any other volunteer (participant). It means that, the driver’s location must not be traced nor vehicle movements [33].

6) ENERGY
By the immense growth of high-data-rate applications, there is a chance that the quality of wireless networks is reducing. Large amount of energy is consumed in remote systems. This cannot be ignored, as it is key factor while merging two concepts, it is possible that there is a rise and fall in energy consumption. It is a challenge, so systematic energy strategies are required [34].

IV. RELATED WORK
In literature, a lot of work has been done in the various domains of VANET and VC. However, these two domains are not investigated together.

Number of studies have focused on the way of communication on the base of IEEE 802.11P, which defines the standard for wireless access in vehicular environments. A substitute to IEEE 802.11p-based VANET, recently investigated the use of cellular technologies due to their low latency and wide range communication. In networks employing IEEE 802.11p only, two problems are highlighted i.e. the broadcast storm and disconnected network at high and low vehicle density degrades the delay and delivery ratio of broadcasting safety message [35].

Number of vehicles on the road is increasing everyday which results in congestion problem and due to this, number of accidents increases. To overcome this issue, VANET introduces few new ideas in terms of traffic controlling and communication between vehicles [36]. The traffic congestion is of two types: recurrent congestion and non-recurrent congestion. The recurrent congestion is projected by the tension between the current traffic flow situation and the road conditions. The non-recurrent congestion is caused by accident or incident, which can lessen the road capacity [37].

Since, battery technology cannot keep up with rising communication expectations therefore, energy management is critical problem in wireless networks. Moreover, energy consumption is reduced with current approaches for energy
conservation in wireless interface either for a given communication task or during remaining idle [38]. However, in the proposed VBVC work, this will be taken into consideration in an innovative way. In above mentioned context, Ashraf [39], proposed MAC protocol for wireless network called neighborhood-based power management (NPM). This particular protocol highlights synchronization and signaling in terms of cost. In NPM, nodes opportunistically attain information about their neighbors. In similar way, we also have nodes (vehicles) acting like volunteers which have neighbor and their relevant information respectively.

Various initiatives have been taken by governments and research organizations in order to develop state-of-the-art VC platforms for higher computations at a low cost. For this purpose, it is needed to maximize the number of personal devices for volunteer use in order to fully exploit VC potentials. For instance, according to [19], BOINC defined as a platform for VC which defines standard processes used by volunteers to get computing power and making their resources available. By running BOINC on computers (hosts), volunteers take part and by attaching along with any computer, one can control a fraction of a resource. Cano performed a project with 175,000 volunteers contributing for the handling of 0.85 million active computing devices. The main challenge faced by VC is the variable nature of its capabilities and unreliability of computing devices. In order to overcome this issue, there is need of more volunteer’s engagement and a proper mechanism for controlling the unreliability of these computing devices. When compared to cloud computing, VC does not incur the cost for researchers, therefore, the use of more computational devices is not limited. VC involves no financial gains, however, it offers scores as a recognition for volunteer contribution. This model overcomes the financial obstacle for accessing computational resources.

High-level computational requirements and minimal participation of volunteers is a problem that needs to be tackled. To overcome this issue, additional computational resources and participation of volunteers is required [4]. In this context, in a volunteer cloud system a multi-state Semi-Markov process-based model is developed to predict future availability and reliability of nodes. This indicates fault tolerance techniques for a volunteer cloud system over reliable and non-dedicated volunteer node [5]. This issue is widely addressed by researchers in cloud computing, however, this is still unexplored domain in vehicular networks. Moreover, a volunteer cloud computing environment uses the extra resources of volunteer devices at the edge of a network to provide cheaper services. Innovative techniques that take the fundamental features of VC in general are needed to completely use the benefits. This is not yet done in the context of vehicles. So, there is a need to implement in Vehicular networks [6]. The CuCloud is another system that can be called a genuine volunteer cloud computing system, which manifests the concept of VCaas that finds significance in edge computing and related applications [7], [8].

Besides this, VC involves less computational efforts as compared to grid computing [40]. VC is a kind of system that uses distributed computing, which allows participants to utilize their idle resources for computational expensive projects [41]. As VC involves billions of users, which specifies more processing and memory therefore, it is important to upgrade existing systems. VC has two important objectives, the first one is to fulfill computational need, and secondly, to involve more volunteers. Moreover, this has put forth stress on minimizing manpower by exploiting low cost computational resources [42].

VC must ensure the following requirements [43].

1) An appropriate division of tasks among specialists i.e., it must ad-here to available resources
2) Scheduling of tasks is required to increase throughout of a system
3) Modelling communication and resources that occur at irregular intervals
4) Volunteers must ensure privacy concerns
5) Security

Along with advantages, VC also faces a number of challenges, particularly in proper distribution of tasks, distribution of the workload, measuring the availability of CPU across many workers, hardware, network heterogeneity, and number use of partial results.

V. PROPOSED VANET-BASED VOLUNTEER COMPUTING (VBVC) APPROACH

After discussing in detail the complete design architecture, application and challenges related to both VANET and VC, there is a need to combine both i.e., VC and VANET which we call VBVC. By merging these two phenomena, it will not only revolutionize networking field, but will also enhance better results in terms of performance, job completion, efficient resource utilization, and QoS etc.

Transmission timing and delay between communicating vehicles are two essential execution measures in VANETs. Moreover, various MAC protocols have been proposed each with changing degrees of effective quality and decency. Wireless configurations such as modern vehicular networks where mobility is a significant challenge, are still an unexplored domain. Modern vehicles equipped with processing and storage capacity represent good computational resources which need to be efficiently utilized. This is our basic motivation for the proposed VBVC. Figure 4 represents the benefits of VC and VANETs.

The reduced execution effect of running a remote workload, expanded equipment representation makes volunteering resources more satisfactory to PC owners. By distributing different tasks to different PCs, we can get significant resources with forceful volunteer registering. To utilize the computational power of idle resources in a way to reduce the cost and time of job completion without delay, motivates us to implement VC concept particular in VANETs. This area indicates the element of the proposed VBVC model which are represented in three different layers, as presented in Figure 5.
The functionalities of the VBVC shown are distributed, where each layer has autonomous functionality and serves the layer above it.

1) **VANET Layer**: The VANET is comprised of vehicles collaborating with each other and with RSU. In VANET, the OBU in a vehicle consists of remote transmitter and recipient. It is fundamentally separated in two significant areas i.e., vehicular area and specially appointed area.

2) **Volunteer Registering Layer**: The volunteer layer consists of the volunteer nodes and data. As VC includes millions of clients, it is important to redesign existing framework which will satisfy the computational needs and will involve more volunteers. Besides, we have to increase volunteers in order to reduce the computational effort.

3) **Presentation Layer**: To achieve benefits from VBVC, we select their characteristic and represent them on presentation layer. Due to environment and circumstances, humans spend most of their time while travelling on roads, therefore, this concept is represented on this layer. By doing so it will enhance the performance of both the VANET and the VC.

**A. MODELING AND ASSUMPTIONS FOR SIMULATIONS**

As discussed earlier, human spends most of their time in travelling. Accumulatively, an individual human spends several hours in vehicles monthly. Still, there are such devices that are resource constrained and they do not have much capacity, so they rely on the neighboring nodes. Therefore, each device could be volunteer and they can help the nearby devices. Job completion is enhanced with this concept without any extra cost.

The system model in Figure 5 represents the elements of proposed VBVC model in different layers. Where each layer has autonomous functionalities and serve the layer above. We use IEEE 802.11p MAC protocol for the proposed VBVC. We expect that packets may get lost because of many reasons, i.e., attenuation and collisions. Along this, it is expected to expect that no extra resource is available to give better quality assurances since communication packets are neither send nor re-transmit.

Some of the key concepts and terms are defined as:

1) **Average node**: The expected number of neighbors connected to a node (vehicle) is referred as average node.
2) Link Probability: Link Probability is the likelihood that a set of two hubs or nodes exist in the transmission scope of one another.

3) Packet Loss: Packet Loss is the likelihood that a given packet broadcast won’t be conveyed to a next node.

4) Packet lifetime: Packet lifetime indicates to the fence length/time after which the vehicles quit rebroadcasting of the message.

5) Energy Saving: Energy savings is well-defined as the difference between the number of transmissions, sustained in restrictive, and plain flooding, required to circulate a safety packet from the point of origin.

B. CASE STUDY

We evaluate the performance of the proposed VBVC concept in detail for two application scenarios.

The first scenario has been a partial success, while the second scenario fully demonstrated the viability of our idea. We created a scenario in VANET where vehicles are communicating with each other and with the RSU. The components of VANET system are the OBU, RSU and the Application Unit (AU). Main functions of OBU are communication with other RSUs or OBUs, wireless radio access, IP mobility, network congestion control, ad-hoc geographical routing and data reliability & security. AU – communicates via OBU with the network solely, which take responsibility for all networking functions and mobility. RSU - is a network device equipped with short range communication based on IEEE 802.11p radio technology for supplying Internet connectivity to OBUs for various communication purposes in a vehicular ad hoc network.

The second scenario is with the proposed VBVC concept, which aims to verify an assumption of a volunteer node registration idea while the first one is without registration i.e., which aims to find a job without any profiling, without knowing the capability of every node. This problem can be modeled and they both need a large amount of computational power to solve, making them good candidates for experimental evaluation of our scheme. In order to remove any ambiguity, we divided the proposed VBVC algorithm in two scenarios containing all the information. For better understanding, additional flow chart had been included (see Figure 7).

Network Manager and Job Manager: Network Manager manages the whole network. It is accountable for managing all the nodes and the job manager. Whereas, a job manager handles scheduling jobs, distributing jobs, assigning resources, profile management etc. A job manager is part of the network, which is managed by the network manager. So, we can say a job manager is under the control of the network manager. Moreover, every volunteer node registers itself to a job manager having all the attributes. Job manager checks for suitable cases. Every volunteer node will register itself with the job manager and the job manager will maintain its profile for performing various computational tasks in the future. The details of all the entities involved in the system and their roles are provided in the Table 2.

C. SCENARIO 1 (WITHOUT NODE Registration)

For this scenario, we make following assumptions:

1) We assume that job distribution is all time available,

2) Job manager always has a job to distribute
A. Amjid et al.: VANET-Based Volunteer Computing (VBVC): Computational Paradigm for Future Autonomous Vehicles

**Algorithm 1 Job Distribution Without Node Registration**

Start;

\(M_{ij}\) Check case switch: Case:

if \((J = N_R)\) then

Service Manager;

if \((N_R <= X_v)\) then

Proceed;

else

Goto \(R_p\);

end

else

\(J = J_c\);

Service Manager;

Verify \(J_c\);

Send to \(N = N_R\);

Discard Entry of \(N\);

end

default: Discard;

End of Switch;

End;

3) Volunteers will always remain volunteers
4) Nodes hardware is fixed
5) All vehicles are within the range of each other by RSU

The working procedure of scenario 1(Without node registration) is presented in Algorithm 1.

**D. DESCRIPTION OF THE PROPOSED ALGORITHM**

In the proposed algorithm for VBVC, the volunteer job manager checks for suitable cases. According to Case I: node \(N\) will get register and check volunteer node cycles. And checks for the volunteer lookup. If the general node is a volunteer node, means if any node is willing to perform the job registered the registration process, then assign available volunteer cycles to volunteer node cycles and update the volunteer node as registered for the task as shown in the line 8. If volunteer job manager does not get any volunteer node for the task, then discard it. In Case II: if the job is an equal requesting node for service then and if a requesting node for service is less than equal to an available volunteer cycle than assign the task to other node else go to registration process. Whereas if you get the requesting node then assign the job \(J\) to the Job completion queue \(J_z\) as shown in the line 20. If not, they will check the status of the job that if it is equivalent to job completion then verify and send it to requesting node.

**E. SCENARIO 2 (WITH NODE REGISTRATION)**

In our second scenario, we consider that nodes will register to the RSU or job manager. We make following assumptions:

1) All vehicles are within the communication range of each other
2) Vehicles on the roadside will be selected reasonably to perform different tasks
3) Vehicles will be registered at an initial stage
4) Job Distribution is not all the time available
5) Job type may differ depending upon the scenario

The working procedure of scenario 2(With node registration) is presented in Algorithm 2.

**F. VARIOUS NODES ACTING DIFFERENTLY**

We have considered a scenario in which there are some non-cooperating nodes. The job manager knows the expected completion time of the job assigned to a node. Furthermore, the job manager also sets a threshold value (ts) in which it must receive a response from a node. If no response is received from a non-cooperating node after the elapse of threshold time (ts), a new node is chosen from the pool and the same job is assigned to the new node.
Algorithm 2 Job Distribution With Node Registration

Start;
\(M_{ij}\) Check case switch: Case: 1
\(J = R_p;\)
\(V_L;\)
if \((N = N_r)\) then
  \(X_v = V_{nc};\)
  Noderegistered \(\rightarrow X_v Updateby;\)
else
  Discard;
end
Case 2;
if \((J = N_R)\) then
  Service Manager;
  if \((N_R <= X_v)\) then
    proceed
  else
    go to \(R_p\)
end
else
  \(J = j_z;\)
  Service Manager;
  Verify \(j_z;\)
  Send to \(N = N_R;\)
  Discard Entry of \(N;\)
end
default: Discard;
End of Switch;
End

VI. EXPERIMENTAL EVALUATION

We used NS-2 to perform the experiments, and generated 1000m\(^2\) topology using Sumo. The topology is consisting of straight roads and intersections, where each road was set to two 2-way lanes, traffic lights were set at intersections. To highlight the authenticity of the simulation, in the network environment, all vehicle nodes changes lane, avoiding, waiting, and overtaking.

In NS-2, the generated mobility model was added. The basic NS-2 parameter settings are shown in Table 3. To send packets with a size of 1500 bytes data streams were randomly generated over the whole network. According to the transmitted information, the size of each beacon packet was calculated. Two situations were set up to simulate the scenario illustrated in Fig. 8, to verify the performance of the VBVC Algorithm effectively.

In the first situation, the maximum speed of the vehicles ranged from 50 km/h to 80 km/h and the number of nodes in the entire network was set to a value around 2-10. In this condition, the discussion will focus on the effect of vehicle density on the routing protocol. At the start of the simulation, the two nodes moved on a fixed route and gradually increases on different roads. The time was set to 300s for each simulation, and was run 10 times, simulation results were compiled by taking average value.

A. RESULTS

To show results for VBVC algorithms and to examine the performance of the proposed approach, we conducted extensive simulations and experiments. In this section, we discuss the experimental results of throughput, data received at each node, job completion rate and latency.

1) THROUGHPUT

Throughput is defined as at per unit time, the rate of total successful packets delivered to the destination.

![FIGURE 8. Throughput.](image)

We present a VBVC model to compute the throughput performance in the presence of a fixed number of nodes and in the assumption of our two scenarios. Figure 8 indicates low performance in Scenario 1 (with blue legend) because there is no registration process which results in packet drop while with node registration approach (Scenario 2), we can see from Figure 8 that performance is better as compared to Scenario 1 and maximum number of packets are recieved.

2) DATA RECEIVED AT EACH NODE

The connection between the number of nodes and the packet delivery ratio represented in Figure 9. The packet delivery
ratio in proposed VBVC algorithm indicates a rising trend as the number of nodes increases. The number of data packets sent by the source node to the ratio of the number of data packets received by the destination node is the packet delivery ratio. Initially, there are only two nodes so the delay is increased but as soon as number of vehicles increase, the delay is reduced. VBVC algorithm revealed a sharp downward trend with increasing number of nodes at certain point. VBVC fully considered the influence of volunteer nodes on link that is why this improvement was achieved. By evaluating the links between nodes, reliability of these links was determined.

3) JOB COMPLETION RATE
In Figure 10, initially, there are few nodes in first scenario where Job Manager sends jobs to all nodes without prior node request and free cycles knowledge. After certain simulation time has elapsed, throughput increases, and all this is based on the node density area.

4) RELATION BETWEEN NUMBER OF NODES AND DELAY
Figure 11 demonstrates, the relation between the number of nodes and end-to-end delay. The packet delivery ratio of registration slowly draws close to that of without registration. The justification for this is that firstly, we have only two nodes, but as the number of nodes increases, the number of volunteer nodes in VBVC (Registration) also increases which lead to decrease in delay. The time delay of both algorithms shows a downward trend as the number of nodes increases. But it can be clearly seen that registration takes time and its slow process.

5) COMPARISON OF LATENCY RATIO
Latency is the time required to produce some result or to perform some action. Latency is usually measured in units of time – nanoseconds, seconds, minutes, hours. Figure 12 demonstrates the association between time and end-to-end delay, where we calculated time delay as the average time taken by the destination node to receive valid data packets. This indicates that with increasing the time, the time delays of algorithms all presented a decreasing trend. Latency ratio: this graph depicts relationship between number of nodes and end-to-end time delay.
VII. CONCLUSION AND FUTURE WORK
In this paper, a novel computational paradigm VBVC has been proposed by merging VANETs with VC with service-oriented infrastructure. This paradigm proposes efficient utilization of idle resources. For evaluation we have used Job Completion, Latency (Job-to-Node), and throughput. In particular with job completion and comparison with simulation, results shows that the VBVC model is 21% better results in terms of job completion. There are a number of improvements that can be made to the proposed model. Our proposed model consists of a single centralized unit, job manager. So, in future we intend to eliminate this centralized unit. This would mean that every node would be intelligent enough and autonomous in sensing and selecting the neighboring nodes with free cycles to execute a job. Furthermore, multiple jobs managers can also be incorporated to study the performance of VBVC paradigm. Incorporating VBVC with cloud computing for studying the job coordination and location-based services could also be an interesting future work. Moreover, we will focus on following: firstly, the proposed technique consists of centralized unit manager, so we are looking forward to work without this manager. Secondly, every node will decide based on an environment for the availability of cycles. Lastly, we will investigate the performance of our proposed scheme with other techniques.

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