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Software defined network-based controller system in intelligent transportation system

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ABSTRACT

Intelligent transportation system (ITS) is meant for redefining the conventional transport by incorporating various analytical features that not only offers safety but also enriches traffic data quality extensively. Review of existing literature shows that there is a significant gap towards utilizing vehicular adhoc network (VANET) for optimal performance in ITS environment. Therefore, this paper contributes towards a simplified and yet intelligent controller system harnessing potential of software defined network (SDN) towards effective directional management of complex transportation system. The novelty of this model is dual-fold. The first novelty is about the usage of locally and globally processed traffic information for undertaking decision towards clearing the waiting vehicles in observation point in specific route segment. The second novelty is associated with relaying of distinct traffic clearance signal to the distinct vehicles unlike any of teh existing transportation management scheme.

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1. INTRODUCTION

With the changing dynamics of transportation system from conventional to intelligent transportation system (ITS), vehicular adhoc network (VANET) has been still proving to be highly essential technology that facilitates various beneficial perspective towards transportation [1]. Some of the prime reason for choosing VANET in ITS system is because of its enhanced road safety [2], traffic management [3], supportability towards emergency services [4], improved navigation system [5], and analytically enhanced information services. Although, it sounds quite good theoretically, but it is quite challenging to implement it on practical ground. Some of the identified challenges in deploying VANET system in ITS are associated with lack of reliability and connectivity issues, privacy concerns, inferior scalability, poor network management, fluctuating quality-of-service, lack of standardization and interoperability [6]–[9]. Apart from this, the dynamic state of vehicular network with vehicular nodes consistently leaving and entering to a network further makes it more challenging to establish a stabilized link [10]. It was also noticed that the power constraints associated with the on-board units in vehicle can also influence the energy efficiency of a VANET. This is essential in order to maintain an overall resources in order to support the networking operation [11]. However, it is also required to highlights the challenges associated with ITS which makes the integration of VANET in ITS slightly non-incompatible as per present state of solutions [12]. An ITS environment encounters a significant challenge in providing the seamless communication as well as interoperability among different types of components. Further, controlling and integrating a massive quantity of traffic data originating from vehicles and different infrastructure units of ITS poses a significant challenge. Although, there are studies related to data storage, sharing, and processing in ITS, still they are yet in its beginning stages [13]. Even if a proper ITS environment has been formed than another hurdle will be to carry out an infrastructure upgrading process. It is because not all the regions will have an updated infrastructure of transportation. Further, integrating ITS into urban planning will potentially involve coordination between technology providers, city planner, and transportation agencies while it is computationally complex process to align all these heterogeneous entities to meet a different level of goal in ITS. Finally, there is a need to offer robust planning and coordination for an ITS system in order to efficiently handle the emergency situations. Hence, both ITS as well as VANET system has their own futuristic scope as well as inherent loopholes, which are required to be addressed.

All these significant issues and gap between VANET and ITS can be solved using software defined network (SDN) owing to its potential capabilities towards an effective traffic management [14]. An administrator can programmatically control as well as adjust the network resources in ITS using specific event, incidents and traffic patterns thereby facilitation more dynamic and real-time traffic management in ITS. This property of SDN is highly contributory towards enhancing overall efficiency of transportation, minimizing congestion, and optimizing traffic flow. Further, SDN can offer higher degree of flexibility, scalability, and interoperation towards deploying VANET system in ITS with reduced operational cost. SDN allows for dynamic and real-time adjustments to network traffic routing. In ITS, this can be applied to dynamically reroute traffic based on current conditions, incidents, or emergencies to optimize traffic flow and minimize congestion. SDN facilitates the dynamic allocation of resources based on demand. In ITS, this is valuable for handling varying traffic loads, ensuring that the network can scale up or down as needed. Therefore, the prime aim of the proposed study is to develop a novel SDN-based controller system which can deploy VANET in ITS with more effectiveness towards controlling and managing dynamic traffic condition. Further, value-added contribution of proposed scheme are presented with respect to research objectives as follows:

- To develop a model for performing processing using both local and global information for SDN controller for better decision making,
- To design an ITS environment with VANET considering on-board units, roadside units, gateway node, and cloud in order to construct a highly collaborative SDN-based framework,
- To construct a novel progressive and non-iterative scheme towards offering a navigational services by the SDN-controller is designed to generate a distinct route to be undertaken considering the distinct requirement of a vehicle to reach their destination.

This section of introduction will further illustrate about the background of study, identified research problem, and proposed solution. This section of introduction discusses about all the related study methodologies deployed toward improving ITS system with respect to communication perspective as a continuation of our prior study [15]. Ali *et al.* [16] have developed traffic model considering conventional adhoc routing protocol for unmanned vehicle. Rai *et al.* [17] have constructed a signalling-based framework where a programmable micro-controller and inductive loops were used for assess the traffic environment. Chowdhury *et al.* [18] have emphasized about addressing issues pertaining to emergency vehicles guidance system considering priority-based management with respect to congestion. Study towards congestion control in VANET is carried out by Nazar *et al.* [19] where a pre-caching methodology is adopted using machine lerarning approach. Ahmed *et al.* [20] have used reinforcement learning scheme in order to structurize the traffic system that supports exchange of heavier multimedia data in VANET. Adoption of reinforcement learning is also witnessed in work of Guo *et al.* [21] that is meant for performing a cooperative control over the connected vehicles.

Beenish *et al.* [22] have presented a Markov modelling scheme towards computing the traffic density in ITS. Kannadhasan *et al.* [23] have presented a systematic framework that is claimed to optimize the data transmission in VANET in order to meet the quality-of-service demands. Makridis *et al.* [24] have presented a control strategy of traffic that can handle varies conflicts among vehicle trajectories. Adoption of k-nearest neighboring algorithm along with dynamic time warping is witnessed to be considered in model presented by Zibner *et al.* [25] emphasizing on encapsuting traffic data for classifying various critical events in ITS. Adoption of deep learning is witnessed in work of Gao *et al.* [26] that is meant for performing predictive analysis of ITS environment. A unique study model is presented by Ma and Zou [27] where traffic noise is used for annalyzing the state of traffic where particle swarm optimization and support vector machine is further used for performing classification of traffic states. Ma *et al.* [28] have constructed a traffic guidance system using game theory with a target to address the issues of clogged traffic. Rafter *et al.* [29] have presented an adaptive controller system which is meant to reduce the delay of vehicles in urban transporation. Adoption of federated learning towards performing predictive analysis is carried out by Sepasgozar and Pierre [30] where long short-term memory (LSTM) can be used to make it decentralized operation. Apart from this, existing system has also witnessed utilizing SDN towards ITS. Huang *et al.* [31] have used reinforcement learning approach for controllong routing operation. Kurungadan and Abdrabou [32] have also presented an SDN-based framework for effective data control in smart city. Masood *et al.* [33] have developed a prioritization scheme in traffic controlling system over SDN-based large scale environment by integrating machine learning with reinforcement learning. Hence, it can be noted that there are various schemes towards improving the performance of ITS considering various case studies with proven beneficial outcomes. However, the above-mentioned studies are not found to combinely address the problems of ITS and VANET using SDN based approach much. The next section of methodoutlines the identified research issues extracted from existing studies.The potential set of identified issues in existing research work are:

- Adoption of learning-based approaches are frequently witnessed with better predictive accuracy but at the cost of higher computational burden associated with it.
- There are lack of frameworks or problem solution where VANET is deployed in typical ITS environment to offer a sustainable communication.
- Majority of the existing approaches towards traffic management is carriedout considering the local data perspective which is not practical approach for large scale global scenario in ITS.
- There is a lack of inclusion of the dynamic and stochastic state of vehicles in any exising models using SDN based traffic management scheme.

Hence, the statement of the research problem is, "it is computationally challenging task to relay a reliable and appropriately calculated information for the vehicular nodes in VANET seeking assistance in large and dynamic environment of ITS."

2. METHOD

The overall research objective is to develop a novel computational model which can harness the potential of SDN and intelligence learning stategy for assisting in effective traffic management in VANET. The core problem addressed by proposed system is to develop highly distributed information propagation mechanism in large scale environment of vehicular network. The development of this part of implementation will be carried out in analytical research methodology. An architecture will be designed exclusively meant for VANET system considering route segments with multiple observation points along with traffic signal in the junction point to manage the traffic. The proposed study considers that complete algorithm is meant to run in two different positions viz. i) on board unit of a vehicle and ii) smart hotspots present in junction point which runs SDN equipped for information propagation and routing in VANET. The Figure 1 highlights the plan of implementation:

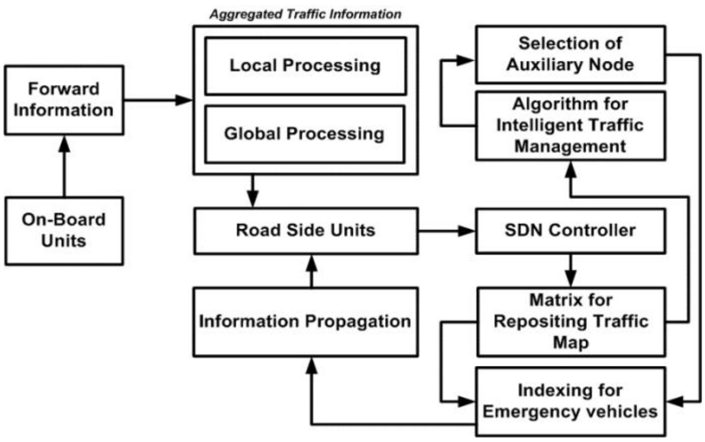

Figure 1. Methodology of proposed solution

The discussion of core operational blocks involved in proposed architecture are as follows:

- On-board units: these are the embedded units deployed within the vehicles and is meant as a communication bridge between the driver/vehicle and external communication environment in vehicular network. All the on-board units (or vehicular nodes) forward its characteristics information of vehicle to road side units installed at the terminals of each lane system approach junction.
- Local/global processing: the collected information is subjected to local processing (about individual vehicles) and to global processing (for all the vehicles present in lane).

- Road-side units: these are the infrastructural units in vehicular network which acts as a bridge of communication between vehicle to another vehicle or other extended infrastructural unit (gateway node).
- SDN controller: this is the core part of the implementation where this controller is assumed to reside in the centre of junction point in urband transportation system. All this aggregated information by road side unit is forwarded to the SDN controller, where the aggregated information is maintained in a matrix.
- Matrix for repositioning traffic map: this is basically a buffer system present within the core VANET system that is meant to retain updated topological information.
- Indexing for emergency vehicles: this is basically module that maintains an indexes of the vehicles in order to differentiate normal and emergency vehicles. This module allocates new indexes for every incoming and existing vehicles are respectively updates the associated shared information among all the infrastructural units.
- Algorithm for intelligent traffic management: this is the prime contribution of proposed system where a novel mechanism is constructed to clear the awaiting vehicles and thereby maintain a better traffic flow. The elements of this matrix for repositioning traffic map further act as an input for proposed algorithm for intelligent traffic management for obtaining best path to be given as an outcome for each vehicle for better communication and navigational system.
- Selection of auxilary node: in order to offer better coverage, the proposed system also identify possible form of an auxiliary nodes, which are normal vehicles, meant for acting as a temporary mobile node to transport adhoc information from one to another vehicular node located in different sensing area but within common sensing area of auxiliary node.

This system assists in better vehicle-to-vehicle communication system. Further, the SDN controller also considers inclusion of indexed emergency vehicles in order to formulate route and offer different and discrete information to every traffic lanes. This is to ensure both emergency vehicles and regular vehicles communication demands are met.

3. ALGORITHM IMPLEMENTATION

This section of algorithm implementationdiscusses about the algorithmic operation carried out towards deploying an SDN-based framework in ITS. A novel SDN-based controller system is designed which is introduced in traffic environment for controlling the flow of transportation system in highly distributed manner. The core idea of the proposed model is to ensure a proper identification of the actual state of traffic in urban transportation system followed by minimizing the queue for waiting vehicles at the junction point. The prime logic for the algorithm development is also to assign a priority-tags for the vehicles with longer waiting time on specific point of routes. Some of the essential attributes considered for this purpose are position of vehicle, its velocity, and its direction. Further node density for each specific route segment connecting the junctions is computed on the basis of number of vehicles traversing on it. Each route segment is initialized with a threshold value of maximum number of vehicles to be accommodated for traversing on that specific route segment. The condition of saturated and unsaturated traffic on each route segment is carried out by comparing the current number of vehicles with this threshold value. Such threshold value can be altered when implemented over real-time application and hence the modelling is carried out in such a way that it can be mapped with any practical environment. The initiation of the algorithm design starts from selecting a primary route out of all the possible routes by the vehicle traversing on a specific route segment, as shown in Algorithm 1.

Algorithm 1: Selection of primary route
Input: α
Output: β
Start
1. Forα= 1:m
2. If (j=n_{state})
3. β=γ^{θ}
4. End
5. End
End

The discussion of the lines of the algorithm is as follows: the algorithm takes the input of α (route segments) that after processing yields an outcome of β (primary route). This computation is carried out within SDN controller system which is assumed to be located at the center of junction point connecting multiple routes in ITS. The algorithm considers m number of joining routes at the junction whose values are typically ranging from 2-5 conventionally in urban area (line-1). The SDN controller system evaluates the state of vehicle nodes (line-2) by considering all the information associated with node density compared with the threshold T to yield four types of node states i.e., very high (n_{den}>>T), high (n_{den}>T), low (n_{den}<<T), and medium (n_{den}=T) score, where n_{den} is node density for specific routes. The next line of operation consists of computing number of possible routes θ from the junction point followed by computing the primary route considering γ i.e., number of constraints to yield β primary route (line-3). This can be illustrated in Figure 2 where it can be seen that a matrix is formulated considering γ i.e., number of constraints to maximum level *max*. Further, each node states will carry an index value assigned by the controller within four different specific ranges with respect to rows and columns i.e., $v_{1,1}$, $v_{2,1}$, …, $v_{max,1}$.

γ	n_{den}>>T	n_{den}>T	n_{den}<<T	n_{den}=T
1	$v_{1,1}$	$v_{1,2}$	$v_{1,3}$	$v_{1,4}$
2	$v_{2,1}$	$v_{2,2}$	$v_{2,3}$	$v_{2,4}$
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
max	$v_{max,1}$	$v_{max,2}$	$v_{max,3}$	$v_{max,4}$

Figure 2. Internal constraint management in SDN controller

It should be noted that Algorithm 1 assists in choosing an appropriate condition of the traffic in particular route segment on the basis of node density in it. The output generated i.e., β (primary route) is further considered as an input for the next part of algorithmic operation towards choosing the optimal route ρ. Hence, Algorithm 2 is responsible to generate a distinct traffic decision by the SDN-controller system considering the local information of current route segment. The steps of the Algorithm 2 are as follows:

Algorithm 2: Route selection by SDN controller
Input: η, β
Output: ρ
Start:
1. For i=1: (η, β)
2. *Jnc*→φ_1(μ, σ)
3. If *Jnc*<T
4. d_{rs}→ φ_2(Jnc, σ)
5. For *l*=1:arg_{max}(λ)
6. If $d_{rs}\leq$ λ
7. ρ=*U*
8. End
9. End
10. End
End

The discussion of Algorithm 2 is as follow: the algorithm takes the input arguments of η (population of nodes) and β (primary route) that after processing yields an outcome of ρ (chosen route). The initiation of the algorithm is carried out by considering the input arguments (line-1) where the evaluation of the traffic state is carried out in the junction point *Jnc* (line-2). For this purpose, a function φ_1 is developed which considers its input argument of μ current route and σ controller decision (line-2). It is to be noted that prime logic of constructing a function φ_1 is to develop a novel structure of junction point in urban environment with more monitoring control over the information acquired from μ current route and σ controller decision. The matrix *Jnc* stores all the global information from other junction points Jnc_1, Jnc_2, … and store them on cloud storage unit that can be accessed at a point of time via the gateway node that are synced with the SDN controller nodes. The elements within the matric *Jnc* are then compared with the threshold T (line-3) while the condition *Jnc*<T will represent an ideal condition ranging between low and medium traffic scenario. This condition also calls for the SDN controller system to clear the vehicle by relaying a clearance decision-based signal. Further, another function φ_2 is constructed which takes the input of junction *Jnc* and σ controller

decision in order to generate decision ruleset of SDN controller d_{rs} (line-4). It should be noted that Algorithm 2 is executed in line with continuous updating process by Algorithm 1 where the primary routes are often updated prior to generate a final decision of route selection by Algorithm 2. The study also considers that the SDN controller is capable of generating λ which are number of traffic decision. It will mean that based on local and global information, the SDN controller system will generate a number of decision pertaining to clearance, waiting, halting with respect to routes to be undertaken by the vehicles. As this information of decision by SDN controller is specific to different vehicles waiting to be cleared from the junction, hence, the numbers of such decision-based information vary depending upon current number of vehicles in the current route. Hence, the algorithm considers multiple conditions ranging from 1 to maximum value of traffic decision $\arg_{max}(\lambda)$ (line-5) followed by further assessing the decision ruleset of SDN controller d_{rs} with number of traffic decision λ (line-6). If the number of decision ruleset of SDN controller system is found to be less than number of traffic decision λ, it will mean that proposed scheme has successfully generated valid number of decisions by SDN controller (line-6). Finally, the controller selects all individual (or decision for local route information) *l* and stores them in global decision for selected routes i.e., ρ (line-7) in form of a matrix. The Relationship between Algorithms 1 and 2 is illustrated in Figure 3.

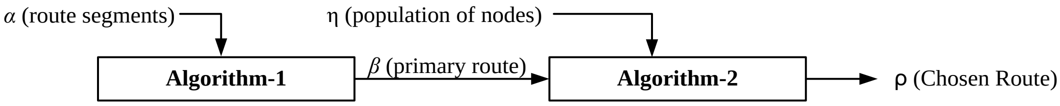

Figure 3. Relationship between Algorithms 1 and 2

The final algorithm is responsible for further optimizing the decision made by the SDN controller system in order to ensure a proper distribution of decision making towards effective traffic management system in urban environment. This was a necessary step as proposed scheme relays a distinct traffic decision uniquely for every vehicle considering the collaborative network and auxiliary nodes. The prime role played by the auxiliary nodes is towards assisting in message propagation between the requesting vehicular node towards the destination without using much infrastructural units. The steps of the Algorithm 3 are as follows:

Algorithm 3: Optimized relaying of traffic decision
Input: c_s, *Jnc*, ρ
Output: σ_{opt}
Start
1. Fori=1:(*Jnc*, ρ)
2. If$c_{init} \geq c_s$
3. param(i)→χ(*Jnc*)
4. Ifρ(*iter*) ≠ ρ(*Jnc*-1)
5. If*iter*≠*f*
6. σ(ρ(*iter*-1), ρ(*Jnc*))=(τ_1, τ_2)
7. *h*=*ψ*
8. σ_{opt}(ρ(i-1), ρ(i))= (τ_1, τ_2)
9 End
10. End
11. End
12. End
End

The discussion of the Algorithm 3 is as follows: the algorithm takes an input of c_s (clearance signal), *Jnc* (Junction point), and ρ (chosen route) that after processing yields an outcome of σ_{opt} (optimized traffic decision). The algorithm first initialized Junction *Jnc* and chosen route ρ (line-1) obtained from Algorithm 2 while analysis is carried out by comparing initialized clearance decision cinit with clearance signal c_s ($c_s \in c_{ds}$) (line-2). If the value of cinit is found to be more than cs than it will mean that there are a greater number of vehicles waiting to be cleared. In such case, the algorithm constructs a parameter *param* which is an array consisting of local controller decision σ, initialized clearance decision c_{nit}, and chosen route ρ. A matrix χ is constructed further to access all the global information of junction point *Jnc* and they are stored back in an array of *param* (line-3). A logical condition is evaluated to assess if the score of the chosen route ρ is not at par with the iteration *iter* is found similar to chosen route ρ corresponding to prior junction (*Jnc*-1) (line-4). Further, it also assesses if the number of iterations iter is not similar to lowest possible number of adjacent routes from junction point *f*. For simplicity the value of *f* can be considered as 2 (line-5). If the condition stated in line-4 and line-5 is found to be true than it will signify multiple number of vehicles in different (global) junctions are also waiting to be cleared. It will eventually mean that the algorithm will require to undertake a decision towards relaying a decision which justifies towards clearning the vehicle not only in present junction but also in all the connected junctions too. Further, the algorithm set up two variables τ_1 and τ_2 which corresponds to two states of chosen routes viz. the first state ρ(*iter*-1) is towards local processing while the second state ρ(*Jnc*) is for global processing with respect to controller decision σ. The value of τ_1 can initialized to medium statistical value of 0.5 while the value of τ_2 can be initialized to lowest score of 0. The system then computes current queue time ψ of vehicles in specific lanes and assign it to global matrix of *h* (line-7). The information is further updated with respect to chosen routes ρ in order to undertake a final decision of optimized controller-based clearance signal σ_{opt} (line-8). The relationship among Algorithms 1 to 3 is shown in Figure 4.

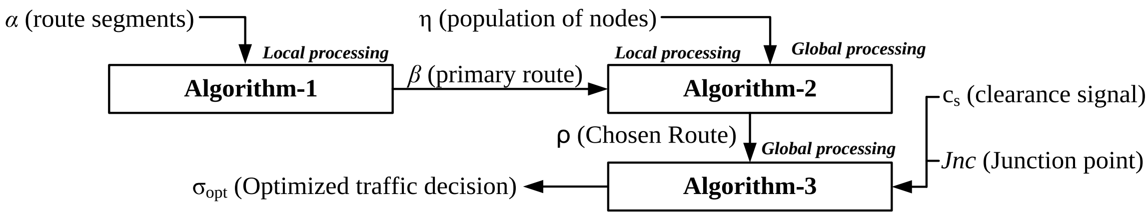

Figure 4. Relationship among Algorithms 1 to 3

However, there are also known challenges associated with implying SDN controller system in vehicular network. Vehicles in a vehicular network move at high speeds, leading to rapid changes in network topology. SDN controllers need to handle fast handovers seamlessly, ensuring continuous connectivity and efficient routing. Vehicular networks can have a large number of vehicles, and scaling SDN controllers to handle the increasing volume of devices and data traffic can be challenging. However, proposed scheme addresses this challenge by effectively introducing a local and global traffic data processing as well as novel SDN-based controller system that is capable of relaying discrete clearance signal to vehicles differing from any conventional scheme.

4. RESULTS AND DISCUSSION

Prior to illustration of the result discussion, it is essential to understand the operation of the proposed study model in practical environment. A sample use-case is shown in Figure 5 where a global scenario of a vehicular network is shown to consists of two regions that are considered as local attributes. SDN controller resides in center of junction and has its own coverage where each SDN controllers are synced among each other via gateway node. Each local regions consist of one gateway node that consists of extensive traffic information that are accesisble by cloud-based environment. Each gateway nodes are further linked to cloud network using streaming server where the traffic information can be disseminated as well as can be stored within the cloud storage units in distributed manner. The prime benefit of this representative use-case is that SDN controller has an accessibility of both local and global traffic information which faciliates quite a reliable as well as practical traffic command for clearing the queues in traffic.

The scripting of the proposed study model is carried out in MATLAB considering 500×500 m of network size with 200 m of route segment. Each vehicle is considered to posses 200 m of transmission range while the vehicle moves with a velocity of 60-80 km/h. Further, the transmission range of roadside unit is also considered as 200 m. The study implementation is assessed with respective to consistency and duration associated with the relaying of the clearance signal by the SDN controller system. Figure 6 showcases all the accomplished outcome of the simulation study. All the above-mentioned evaluation are carried out considering 150 number of iteration where each iteration represents increment in traffic size randomly. Figure 6(a) showcases that performance outcome of consistency in relaying clearance signal for all the four observations point. The observation point is considered as location of junction where the SDN controller is installed. The performance parameter consistency in relaying clearance signal represents total number of the primary routes generated as a consequence of Algorithm 1 for all the observation points. A closer look into

Figure 6(a) showcases that there is a good amount of consistency for almost all the respective observation points in every round of iteration.

This analysis is carried out by dynamic presence of emergency vehicles by suddenly relaying a request to SDN controller system for optimal route towards destination while the controller had no predefined knowledge of that node as an emergency node. This represents that proposed scheme can offer a better form of equilibrium between normal and non-predefined emergency vehicle. The outcome of Figure 6(b) represents duration of route selection by controller which is basically a consequence of Algorithm 2. Although, the duration is found to be slightly increased for higher iteration rounds, but majority of the iteration round is found to maintain a nearly-similar duration values with least significance differences with increasing iteration. The prime reason behind this is an effective syncing among all the roadside units with the SDN controller system, while SDN controller system will only have local information access, their coverage towards accessing global information is boosted by their synced connectivity with roadside units that are linked with local gateway, while all the gateways are lined to cloud. Hence, decision-making doesn't undergo much time towards route generation by an SDN controller.

Figure 6(c) showcases the duration required for relaying the optimal signal considering all the global information by the SDN controller. A closer look into the trend of the bars shows that there is an approximately reduction of 60% of time period for relaying the optimal signal in contrast to Figure 6(b) for all the observation points. The prime justification behind this significantly reduced duration is because of the broader accessibility of navigational routes accessed by the SDN controller using Algorithm 3.

Figures 6(d) and 6(e) exhibits the practical proof-of-concept for the effectiveness of proposed scheme towards clearing the vehicles thereby reducing the waiting time in the observation point. Further, reduction in waiting time can also be proven by the outcome exhibited in Figure 6(c). Figure 6(d) exhibts that different observation points to receive different values of relayed clearance signal by the SDN controller while Figure 6(e) exhibits that overall clearance of vehicles from all the observation point from global perspective. This analysis is carried out by calculating the total number of vehicles being cleared from all the individual respective observation points in complete simulation area. The outcomes showcases that in least duration, each observation points are capable to clear minimal 400-800 number of vehicles considering the complete simulation area. A closer look into the analytical outcomes also shows that the performance of existing literatures [16]-[33] are must restricted to one segment considering local variables of respective parto of the road, whereas proposed scheme is implemented considering global attributes of traffic environment. This consideration in implementation plan of proposed system makes it more applicable towards practical traffic management in vehicular network.

Table 1 highlights the comparison of the proposed system with existing literatures with respect to adopted methodology, network type supportability, and possible limitation. It is explored that proposed system is capable of addressing concurrent request deploying its SDN controller in order to make definite decision of clearning the vehicles from junction points. Apart from this, it also supports highly distributed and decentralized network which is not reported in existing reviewed methodologies towards traffic management. This is the prominent novelty and significance of proposed study.

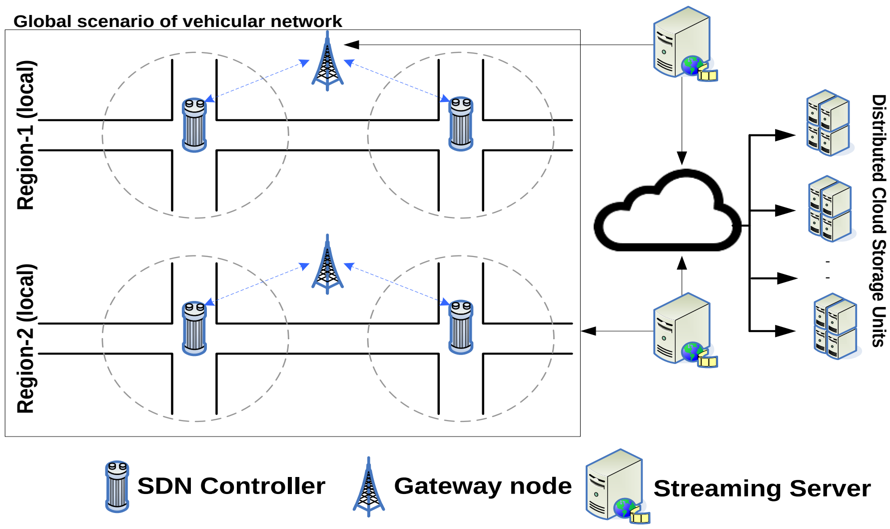

Figure 5. Case study of proposed model

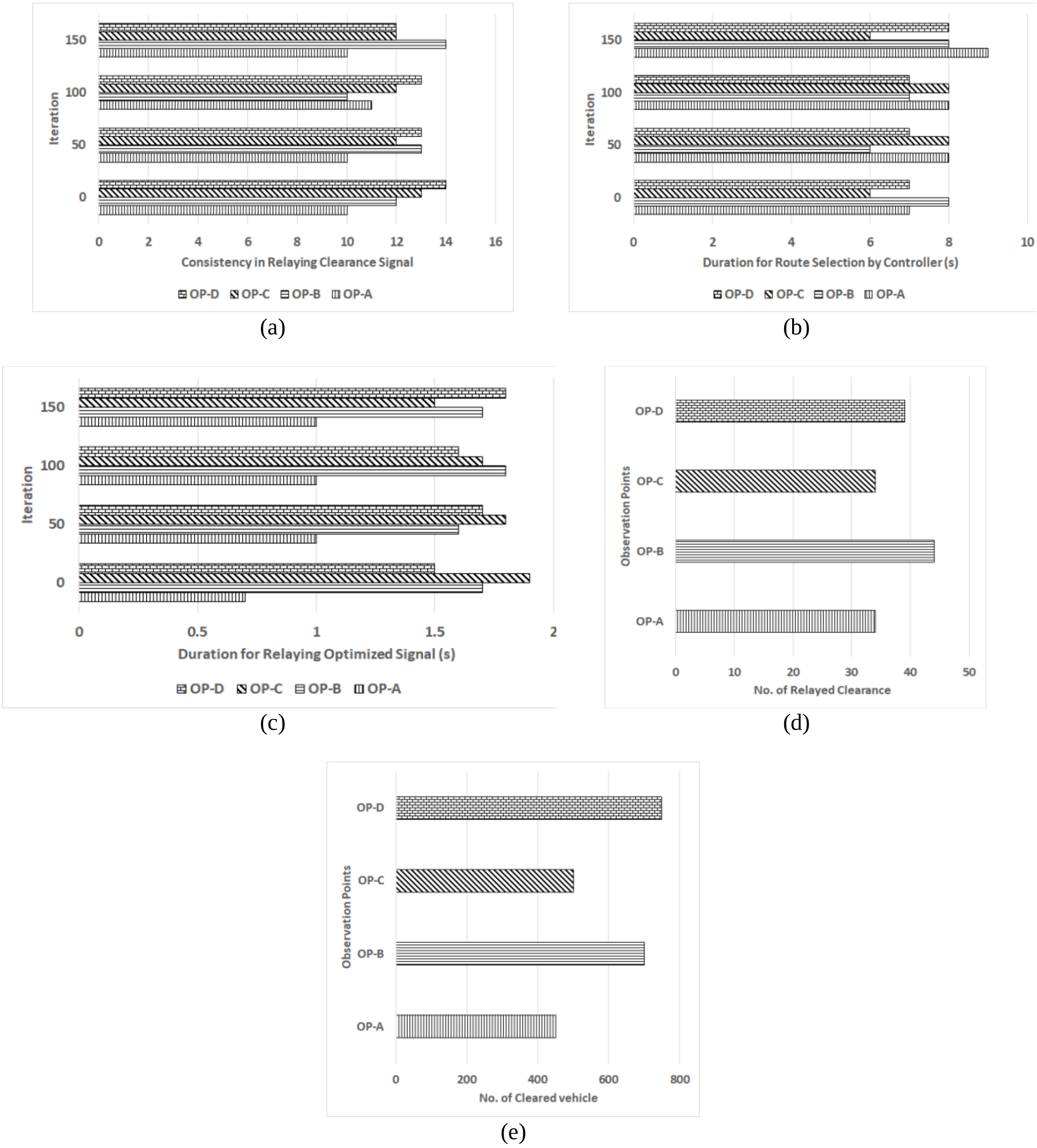

Figure 6. Evaluation of graphical outcome of proposed model: (a) consistency in relaying clearance signal, (b) duration for route selection by controller, (c) duration of relaying optimized signal, (d) number of relayed clearances, and (e) number of cleared vehicles

Table 1. Comparison with existing literature

Approaches	Methodology	Network type	Limitation
Ali *et al.* [16]	Conventional routing	Centralized	Limited coverage
Rai *et al.* [17]	Signaling-based	Centralized	Small network
Chowdhury *et al.* [18]	Vehicle prioritization	Peer-to-peer	Small area coverage
[19]-[22], [26], [30], [31]	Machine learning, Markov modelling, deep learning	Centralized	Cannot respond emergency event
[23]-[25], [29]	Analytical, data driven	Centralized	Cannot meet dynamic demands
Ma and Zou [27]	Particle swarm optimization	Centralized	Extensive computational demand
Ma *et al.* [28]	Game theory	Centralized	Cannot model complex logic
[32], [33]	SDN	Centralized	Cannot cater up dynamic demands
Proposed	Analytical	Distributed, decentralized, large network	Demands more calibration towards optimization

5. CONCLUSION

The proposed study has presented a novel SDN-based framework which can acquire contextual information both from local and global environment in order to undertake a decision of service relaying. The work has been carried out considering VANET deployment to support functionally working in large ITS environment. The summary of contribution and novelty associated with the proposed study are as follows: i) a faster and contextual decision-making support system has been presented which can meet the routing demands in complex traffic environment, ii) the proposed scheme introduces a collaborative method which entitles the SDN controller system to access both local and global information in order to undertake decision making for clearing the awaiting vehicles in observation point, iii) different from conventional traffic signalling process, the proposed scheme offers a novel feature of relaying a discrete set of decision for all the vehicles uniquely such that it can address the dynamic and stochastic properties of the vehicular movement in ITS, and iv) the proposed scheme introduces a complete decentralized strategy towards traffic management with lesser dependencies on extensive number of traffic data to undertake decision. The future work of the proposed system will be continued in the direction of further optimizing the traffic management module by involving various challenging environment. The idea of next-level of work will also be to investigate the impact of various network-related artifacts on the performance attributes. This agenda of work will be towards a better calibrated traffic management model in urban transportation system.

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